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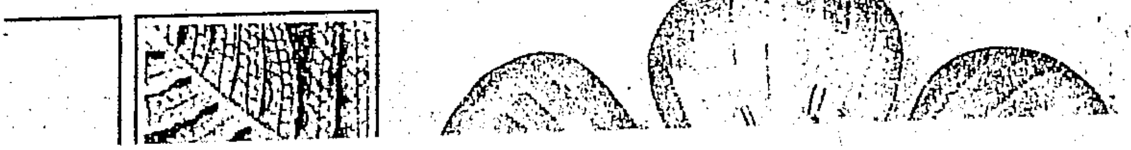

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A MASTER BOOK FOR

[CPMT, PMT, CBSE, BHU, AMU, AIIMS, AFMC, JEE (ORISSA), BCECE,
EAMCET and All Other Medical Entrance Examinations]

{Since I gave up hope. I feel much better!}

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PREFACE TO THE THIRD EDITION

We are delighted to present the third revised edition of this book "G.R.B. Objective Botany" within a short span of time and are extremely pleased that this book has received a overwhelming response of all concerned.

The book has been thoroughly revised along with rectification of mistakes coming to our knowledge. Every possible effort has been made to make the book error-free. Some new and novel points have been incorporated at different places in text. Besides questions of 2003 Medical Entrance Examinations have been added in each chapter. Valuable and positive comments and suggestions of colleagues and students are always welcomed for improvement of the book. Special thanks are to our friends, colleagues and children especially Shivani for their constant help in different ways.

We are thankful to our publisher Sh. Prakash Chand Bathla for the pains and interest taken in bringing third revised edition of the book. Staff of Prakash Publications deserves special thanks for the constant hard work in bringing out third revised edition of this book.

Above all, we are thankful of 'Almighty'.

464/113, Suman Vihar,
Civil Lines South,
Muzaffarnagar (U.P.)
June, 2004

Dr. Naresh Kumar
Mrs. Jaishree Malik

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PREFACE

The present book "G.R.B. Objective Botany" has been written for complete and thorough preparation of Medical Entrance Examinations. The present effort has been made keeping in view the difficulties faced by students preparing for different medical entrance examinations. We hope that this book will help average as well as brilliant students in getting through competitions. This book is having 9 units and 27 chapters in which up-to-date required text along with necessary lebelled diagrams for clear understanding of subject matter has been given. Important points of the subject matter have been marked with dots (•) and most important distinct points have been marked with asterisk (✪) so as to draw the attention of students. Similarly some key-points are in bold so as to make them clear at a glance. Some new topics recently incorporated in syllabi of different Medical Entrance Examinations, have been added, *e.g.,* energy flow in the life of cell, Genetic Engineering (including Restriction enzymes, Recombinant DNA technology, PCR, Molecular probes, Blotting pattern, DNA finger printing, etc.), Genomics, Neurospora genetics, Major Biomes, Biodiversity, etc. Special mention is of Unit - 9, *i.e.,* Applications of Biology (Biology in Human Welfare), where six recent topics (included in syllabus by NCERT this year) have been incorporated in this Edition - 2002. These include Transgenic plants/crops, Genetically modified foods (GM foods), Biopatent, Biopiracy, Biotechnology and Sustainable Agriculture and Bio-war, which are perhaps not there in any other objective books available for preparation of Medical Entrance Examinations. At the end of each chapter, a large number of multiple choice questions have been given touching each and every corner of the chapter. These questions also include questions asked in different Medical Entrance Examinations. Further at the end of each chapter, explanation of selected questions has been given for clear understanding. At the end of each unit, Unit Test Paper and Assertion-Reason Type Questions have been given. At the end of the book, five self-evaluation tests and important discoveries of some scientists have been given. This edition contains plus 10,000 questions to increase and test the subject knowledge. Answers to all questions have been verified from standard books.

The language of this book is lucid and easily understandable. Though every possible effort has been made to make the book error-free, but still there are chances of some minor mistakes due to invisibility. So colleagues and students are requested to bear with us and their kind co-operation is required for improvement in the next edition of this book. Their valuable comments and suggestions for improvement of this book will always be welcomed.

We have been encouraged by our parents, teachers, colleagues, friends and students in completion of this book. Our children Shivani, Kriti and Shivashish deserve special thanks for their constant help in different ways.

We are extremely thankful to our publisher Sh. Prakash Chand Bathla for the pains and interest taken in bringing out this thorougly revised edition of the book within a short span of time. Whole staff of Prakash Publications who have worked hard for months and have left no stone unturned in bringing out this book in present form deserve special thanks.

Above all, we are thankful to 'Almighty'.

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July, 2002

Dr. Naresh Kumar
Mrs. Jaishree Malik

CONTENTS

UNIT 1

29

1. GENERAL INTRODUCTION 3–12
   - ○ Nature and Scope of Biology 3
   - ○ Characters of Living Organisms 3
   - ○ Differences between Plants and Animals 4
   - ○ Branches of Botany and Famous Workers Associated with Them 5
   - ○ Some Famous Botanical Research Centres, Institutes and Gardens 7
   - ○ Units of Measurements in Biology 7
   - ○ Multiple Choice Questions 8
   - ○ Answers 12
   - ○ Explanation of Selected Questions 12
2. CLASSIFICATION AND DIVERSITY OF PLANT KINGDOM 13–22
   - ○ Fundamental Classifications 13
   - ○ Eichler's Classification 13
   - ○ Tippo's Classification 14
   - ○ Whittaker's Classification 16
   - ○ Six Kingdom Classification 17
   - ○ Diversity in Plants 17
   - ○ Multiple Choice Questions 19
   - ○ Answers 22
   - ○ Explanation of Selected Questions 22

☐ **Test Paper – Unit - 1** 23
- — Answers 25

☐ **Assertion and Reason-Type Questions** 26
- — Answers 26

UNIT 2

30 [illegible] 1

3. TOOLS AND TECHNIQUES USED IN CYTOLOGY 29–39
   - ○ Microscopes 29
     - — Compound or Light Microscope 29
     - — Phase Contrast Microscope 29
     - — Dark-field Microscope 29
     - — Interference Microscope 30
     - — Fluorescence Microscope 30
     - — Polarizing Microscope 30
     - — Ultraviolet Microscope 30
     - — Electron Microscope 30
   - ○ Sectioning 30
   - ○ Staining 30
   - ○ Cytochemistry 31
   - ○ Microspectrophotometry 31
   - ○ Cell Fractionation 31
   - ○ Autoradiography 31
   - ○ Chromatography 31
   - ○ X-Ray Crystallography 32
   - ○ Multiple Choice Questions 33
   - ○ Answers 39
   - ○ Explanation of Selected Questions 39
4. STRUCTURAL AND FUNCTIONAL ORGANIZATION OF CELL 40–98
   - ○ Meaning of Cytology and Brief History 40
   - ○ Cell Theory 40
   - ○ Size, Number, Shape and Types of Cells 40
   - ○ Differences between Prokaryotic and Eukaryotic Cells 41
   - ○ Organization of Cell 42
   - ○ Cell Wall 42
   - ○ Plasma Membrane or Cell Membrane 44
   - ○ Vacuole 45
   - ○ Protoplasm 45
   - ○ Cytoplasmic Organelles 46
     - — Mitochondria 46
     - — Plastids 47
     - — Endoplasmic Reticulum 49
     - — Golgi Complex 50
     - — Ribosomes 51
     - — Microbodies 52
     - — Centrosome 53
     - — Cilia and Flagella 54
     - — Cytoskeleton 54
   - ○ Nucleus 54
   - ○ Chromosomes 56
   - ○ Metabolically Inactive Substances or Deutoplasmic Substances 59
   - ○ Differences between Plant and Animal Cell 64
   - ○ Multiple Choice Questions 65
   - ○ Answers 96
   - ○ Explanation of Selected Questions 98
5. ENERGY FLOW IN THE LIFE OF A CELL 99–107
   - ○ Energy 99
   - ○ Laws of Thermodynamics 99
   - ○ Exergonic and Endergonic Reactions 101
   - ○ Energy Carriers and Electron Carriers in the cell 102
   - ○ Controlling Metabolic Reactions 104

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○ Multiple Choice Questions 105
○ Answers 107
○ Explanation of Selected Questions 107

6. CELL DIVISION 108–127
○ Meaning of Cell Division 108
  — Why a Cell Divides ? 108
○ Types of Cell Division 108
  — Mitosis 109
  — Meiosis 110
  — Free Cell Formation 113
  — Amitosis 113
  — Budding 113
○ Differences between Mitosis and Meiosis 113
○ Karyotype Analysis 114
○ Multiple Choice Questions 116
○ Answers 126
○ Explanation of Selected Questions 127
☐ **Test Paper – Unit - 2** 128
  — Answers 129
☐ **Assertion and Reason Type Questions** 130
  — Answers 132

UNIT 3

7. MOLECULAR BIOLOGY 135–161
○ Nucleic Acids 135
○ Evidences in Favour of DNA as Genetic Material 135
○ DNA 136
○ Differences between RNA and DNA 139
○ Types of Non-Genetic RNA 140
○ Autocatalytic Functions of DNA 141
  — Replication 141
  — Transcription 141
  — Translation 142
○ Operon Model 142
○ Gene and Gene Action 143
○ Molecular Structure of Gene 144
  — Cistron 144
  — Muton 144
  — Recon 144
○ Transposons or Jumping Genes 144
○ Retroposons 144
○ Split Genes 144
○ Pseudo Genes 144
○ Inducible Genes, Repressible Genes and House-Keeping or Constitutive Genes 144
○ Genetic Code 144
○ Genetic Engineering 145
○ Genomics : Principles and Applications 147
○ The Human Genome 148
○ Multiple Choice Questions 149
○ Answers 160
○ Explanation of Selected Questions 161

8. GENETICS 162–206
○ Introduction and Historical Background 162
○ Mendelism or Mendel's Laws of Inheritance 162
○ Some Problems 165
○ Back Cross 165
○ Test Cross 165
○ Modification of F_2 Ratios or Interaction of Factors 166
  — Incomplete Dominance 166
  — Lethal Factors 166
  — Complementary Factors 168
  — Supplementary Factors 169
  — Epistatic Factors 169
  — Inhibitory Factors 170
  — Duplicate Factors 170
  — Polymeric Factors 170
○ Some other Patterns of Inheritance 172
  — Multiple allelism 172
  — Pleiotropy 172
○ Linkage 172
○ Crossing Over 174
○ Structural Changes in Chromosomes 176
○ Numerical Changes in Chromosomes 176
○ Mutations 179
○ Cytoplasmic or Extranuclear Inheritance 180
○ Sex Linked Traits and their Inheritance 180
○ Sex-Determination 182
○ Neurospora Genetics 183
○ Biochemical Mutations in *Neurospora* 184
○ Multiple Choice Questions 185
○ Answers 205
○ Explanation of Selected Questions 206
☐ **Test Paper – Unit - 3** 207
  — Answers 208
☐ **Assertion and Reason Type Questions** 209
  — Answers 210

UNIT 4

9. BACTERIA, MYCOPLASMA AND VIRUSES 213–243
○ Bacteria 213
  — Historical Features 213
  — Characteristic Features 213
  — Gram-negative and Gram-positive Bacteria 213
  — Distribution and Habitat 214
  — Form and Morphology 214
  — Shapes of Bacteria 214
  — Classification of Bacteria on the Basis of Flagellation 214

— Structure of Bacterial Cell 214
— Nutrition 216
— Reproduction 216
— Importance of Bacteria 217
• Useful Activities 217
• Harmful Activities 218
○ Characteristic Features of *E. coli* 218
○ Spirochaetes 219
○ Actinomycetes 219
○ Archaebacteria 219
○ Cyanobacteria 219
○ Mycoplasma 220
— Historical Features 220
— Characteristic Features 220
— Culture of Mycoplasma 220
— Structure of Mycoplasma 220
— Difference between L-form Bacteria and Mycoplasma 220
— Reproduction 220
— Evolutionary Significance 221
— Diseases Caused by Mycoplasma 221
○ Viruses 221
— Historical Features 221
— Characteristic Features 221
— Classification 221
— Nomenclature 221
— Morphology and Structure 221
— Chemical Composition 222
— Symmetry of Viruses 222
— TMV 222
— Influenza Virus 222
— Bacteriophages 222
— Mycophages 223
— Viroids 223
— Prions 223
— Virion 224
— Interferons 224
— Diseases Caused by Viruses 224
○ Multiple Choice Questions 225
○ Answers 242
○ Explanation of Selected Questions 243
10. ALGAE 244–270
○ General Characters 244
○ Famous Algologists 244
○ Habitat of Algae 244
○ Range of Vegetative Structure in Algae 245
○ Variation in Shape, Size and Number of Chromosomes in Algae 245
○ Reproduction in Algae 246
○ Classification of Algae 246
○ Economic Importance of Algae 248
○ Life Cycle of *Chlamydomonas* 249
○ Life Cycle of *Ulothrix* 251
○ Life Cycle of *Spirogyra* 254
○ Multiple Choice Questions 257
○ Answers 269
○ Explanation of Selected Questions 270
11. FUNGI AND LICHENS 271–303
○ Fungi—General Introduction 271
○ Similarities of Fungi with Algae 271
○ Differences between Algae and Fungi 271
○ Famous Mycologists 271
○ Habitat of Fungi 272
○ Structure of Fungi 272
○ Classification of Fungi 273
○ Some Common Names of Fungi 274
○ Reproduction in Fungi 275
○ Economic Importance of Fungi 276
○ Life Cycle of *Rhizopus* 277
— Heterothallism 279
○ Life Cycle of Yeast 280
○ Economic Importance of Yeast 282
○ Characteristic Features of Some Other Important Fungi 283
— Albugo 283
— Puccinia 283
— Agaricus 285
○ Lichens—General Introduction 286
○ Habitat of Lichens 286
○ Classification of Lichens 286
○ Some Special Structures Associated with Lichen Thallus 287
○ Reproduction in Lichens 287
○ Economic Importance of Lichens 287
○ Multiple Choice Questions 289
○ Answers 302
○ Explanation of Selected Questions 303
12. BRYOPHYTA 304–328
○ Introduction of Bryophyta 304
○ Main Characteristics of Bryophytes 304
○ Distribution and Habitat of Bryophytes 305
○ Classification of Bryophytes 305
○ Characteristic Features of Different Classes of Bryophytes 306
— Hepaticopsida 306
— Anthocerotopsida 306
— Bryopsida 306
○ Vegetative Reproduction in Bryophytes 307
○ Importance of Bryophytes 307
○ Important Points to Remember 307
○ Life Cycle of *Riccia* 308
○ Life Cycle of *Funaria* 312
○ Multiple Choice Questions 317
○ Answers 328
○ Explanation of Selected Questions 328
13. PTERIDOPHYTA 329–354
○ General Characters 329
○ Resemblances between Bryophytes and Pteridophytes 330

○ Differences between Bryophytes and Pteridophytes 330
○ Eusporangiate and Leptosporangiate Type of Development of Sporangium in Pteridophytes 330
○ Classification of Pteridophytes 330
○ Some Important Points about Pteridophytes 331
○ Stelar System in Pteridophytes 331
○ Life Cycle of *Selaginella* 333
○ Life Cycle of *Dryopteris* (Fern) 339
○ Multiple Choice Questions 344
○ Answers 354
○ Explanation of Selected Questions 354

14. GYMNOSPERMS ✓ 355–383
○ General Introduction 355
○ Distribution and Habitat 355
○ General Characters of Gymnosperms 355
○ Classification 356
○ Economic Importance of Gymnosperms 357
○ Life Cycle of *Cycas* 358
○ Life Cycle of *Pinus* 365
○ Multiple Choice Questions 374
○ Answers 383
○ Explanation of Selected Questions 383
☐ Test Paper – Unit - 4 384
— Answers 386
☐ Assertion and Reason Type Questions 387
— Answers 389

UNIT 5

9 , 10

15. MORPHOLOGY OF ANGIOSPERMS 393–428
○ Angiospermic Plant and Forms of Angiosperms 393
○ The Root 394
— Characters of Root 394
— Zones or Parts of Root 394
— Types of Roots 395
— Modifications of Roots 395
— Functions of Roots 397
○ The Stem 397
— Characters of Stem 397
— Buds 397
— Modification of Buds 398
— Types or Forms of Stems 398
— Modifications of Stem 399
— Functions of Stem 402
○ The Leaf 402
— Types of Leaves 402
— Parts of a Foliage Leaf 402
• Leaf Base 402
• Petiole 404
• Lamina 404
— Venation 406
— Vernation and Ptyxis 407
— Simple and Compound Leaves 407
— Phyllotaxy 409
— Modifications of Leaves 409
— Functions of Leaf 410
○ Inflorescence 411
○ Flower 411
○ Fruit 411
○ Seed 411
— Parts of Seed 411
— Seed Germination 412
— Seed Dormancy 413
○ Multiple Choice Questions 415
○ Answers 427
○ Explanation of Selected Questions 428

16. FRUITS AND DISPERSAL OF SEEDS AND FRUITS 429–441
○ Fruits 429
— Types of Fruits 429
— Dehiscence of Fruits 431
— Edible Parts of Some Fruits 431
○ Dispersal of Seeds and Fruits 431
— Anemochory 431
— Hydrochory 432
— Zoochory 432
— Autochory 432
○ Multiple Choice Questions 433
○ Answers 440
○ Explanation of Selected Questions 441

17. EMBRYOLOGY OF ANGIOSPERMS 442–479
○ Meaning 442
○ Historical Background 442
○ Flower and its Parts 443
○ Homologies of Flower Parts 443
○ Evolution of Flower 443
○ Anther and Microsporogenesis 444
○ Development of Male Gametophyte 447
○ Ovule and Megasporogenesis 448
○ Development of Female Gametophyte or Embryo Sac in Angiosperms 450
○ Pollination 452
○ Coevolution of Flowers and Pollinators 453
○ Fertilization 454
○ Endosperm 455
○ Embryo 457
○ Formation of Seed and Fruit 457
○ Alternation of Generations in Angiosperms or Life History of Angiosperms 458
○ Polyembryony 459

○ Apomixis 460
○ Parthenocarpy 460
○ Experimental Embryology or Applied Embryology 460
○ Multiple Choice Questions 462
○ Answers 478
○ Explanation of Selected Questions 479

18. PLANT ANATOMY 480–517
○ Introduction 480
○ Meristems or Meristematic Tissue 480
  — Characteristics 480
  — Classification 480
  — Shoot Apex Organization 481
  — Root Apex Organization 482
○ The Tissue 483
  — Simple Permanent Tissues 483
    • Parenchyma 483
    • Collenchyma 483
    • Sclerenchyma 484
  — Complex Permanent Tissues 485
    • Xylem 485
    • Phloem 486
  — Special or Secretory Tissues 487
○ Tissue System 487
  — Epidermal Tissue System 487
  — Ground Tissue System 488
  — Vascular Tissue System 489
○ Types of Vascular Bundles 489
○ Anatomy of Root 490
  — General Characters 490
  — Orchid Root 490
  — Differences between Dicot and Monocot Root 490
  — Origin of Lateral Roots 491
  — Origin of Adventitious Roots 491
  — Heterarchy in Roots 491
  — Contractile Roots 492
○ Anatomy of Stem 492
  — General Characters 492
  — Differences between Anatomy of Root and Stem 492
  — Differences between Anatomy of Monocot and Dicot Stem 493
  — Root-Stem Transition 493
○ Anatomy of Leaf 493
  — Dorsiventral Leaves 494
  — Isobilateral Leaves 494
  — Differences between Dicot and Monocot Leaf 495
  — Leaf Abscission or Leaf Fall 495
○ Secondary Growth 495
  — Secondary Growth in Dicot Stem 495
  — Annual Rings 496
  — Heart Wood and Sap Wood 496
  — Tyloses 496
  — Cork Cambium 497
  — Bark 497
  — Rhytidome 497
  — Lenticels 497
  — Secondary Growth in Dicot Root 497
  — Cork Cambium Activity in Roots 497
  — Some Abnormal Features 497
○ Multiple Choice Questions 499
○ Answers 516
○ Explanation of Selected Questions 517
☐ **Test Paper – Unit - 5** **518**
  — Answers 519
☐ **Assertion and Reason Type Questions** **520**
  — Answers 521

UNIT 6

19. TAXONOMY OF ANGIOSPERMS OR SYSTEMATIC BOTANY 525–568
○ Meaning 525
○ Nomenclature 525
○ Binomial System of Nomenclature 525
○ International Code of Botanical Nomenclature 526
○ Classification of Angiosperms 527
○ Herbarium 531
○ Botanical Gardens 531
○ Botanical Survey of India 531
○ Important Taxonomic Terms 531
○ Inflorescence 532
○ Flower 533
○ Calyx 534
○ Corolla 535
○ Androecium 536
○ Gynaecium or Pistil 537
○ Families 538
  — Brassicaceae 538
  — Malvaceae 539
  — Fabaceae 540
  — Papilionaceae 540
  — Caesalpiniaceae 542
  — Mimosaceae 543
  — Cucurbitaceae 543
  — Compositae 545
  — Solanaceae 546
  — Liliaceae 548
○ Main Points of Some Other Families 549
    • Ranunculaceae 549
    • Poaceae 550
○ Multiple Choice Questions 551
○ Answers 567
○ Explanation of Selected Questions 568

20. PLANTS AND HUMAN WELFARE 569–599
- ○ Introduction 569
- ○ Food Plants 569
  - — Cereals 569
  - — Millets 570
  - — Pseudocereals 570
  - — Pulses 571
  - — Nuts 571
  - — Vegetables 572
  - — Fruits 573
- ○ Woods 573
- ○ Cork 574
- ○ Rubber 574
- ○ Fibres 575
- ○ Tannins 575
- ○ Dyes 575
- ○ Sugars 576
- ○ Starch 576
- ○ Fumitories and Masticatories 576
- ○ Non-alcoholic Beverages 577
- ○ Spices and Condiments 577
- ○ Essential Oils 577
- ○ Fatty Oils 578
- ○ Medicinal Plants 579
- ○ Paper 580
- ○ Old World and New World Crops 580
- ○ Multiple Choice Questions 581
- ○ Answers 598
- ○ Explanation of Selected Questions 599

☐ **Test Paper – Unit - 6** 600
- — Answers 601

☐ **Assertion and Reason Type Questions** 602
- — Answers 603

UNIT 7

11 . 12

21. PLANT PHYSIOLOGY (I) 607–625
- ○ General Introduction 607
- ○ Famous Indian Physiologists 607
- ○ Diffusion 607
  - — Factors Affecting Diffusion 607
  - — Diffusion Pressure 608
- ○ Osmosis 608
  - — Osmotic Pressure 608
  - — Exosmosis and Plasmolysis 608
  - — Endosmosis and Deplasmolysis 609
- ○ Turgor Pressure 609
- ○ Wall Pressure 609
- ○ Diffusion Pressure Deficit 609
- ○ Relationship between Diffusion Pressure Deficit, Osmotic Pressure and Turgor Pressure 609
- ○ Water Potential 609
- ○ Imbibition 609
- ○ Absorption of Water 610
  - — Active Water Absorption 610
  - — Passive Water Absorption 611
  - — Factors Affecting Water Absorption 611
- ○ Ascent of Sap 611
  - — Root Pressure Theory 612
  - — Vital Force Theories 612
  - — Physical Force Theories 613
- ○ Multiple Choice Questions 614
- ○ Answers 624
- ○ Explanation of Selected Questions 625

22. PLANT PHYSIOLOGY (II) 626–648
- ○ Transpiration 626
  - — Meaning 626
  - — Differences between Transpiration and Evaporation 626
  - — Magnitude of Water Loss in Transpiration 626
  - — Types of Transpiration 626
  - — Transpiration Ratio 627
  - — Stomata 627
  - — Distribution of Stomata on Leaf Epidermis 627
  - — Mechanism of Stomatal Movements 627
  - — Scotoactive Stomata 628
  - — Daily Periodicity of Stomatal Opening 628
  - — Factors Affecting Transpiration 628
  - — Antitranspirants 629
  - — Significance of Transpiration 629
- ○ Guttation 629
  - — Differences between Transpiration and Guttation 630
- ○ Mineral Nutrition 630
  - — Meaning 630
  - — Composition of Plant Ash 630
  - — General Functions of Mineral Elements 631
  - — Critical Elements 631
  - — Study of Significance of Elements for Plants 631
  - — Specific Roles of Different Elements 631
  - — Liebig's Law of Minimum 632
- ○ Mineral Salt Absorption 632
  - — General Characters 632
  - — Mechanism of Mineral Salt Absorption 632
  - — Factors Affecting Mineral Salt Absorption 632
- ○ Multiple Choice Questions 633
- ○ Answers 647
- ○ Explanation of Selected Questions 648

23. ✓ PLANT PHYSIOLOGY (III) 649–672
- ○ Photosynthesis 649
  - — General Concept of Photosynthesis 649
- ○ Significance of Photosynthesis 649
- ○ Historical Background 649
- ○ Mechanism of Photosynthesis 650

— Light Reaction of Photosynthesis 650
  • Red Drop 650
  • Emerson Enhancement Effect 650
  • Production of Assimilatory Powers 651
— Dark Reaction of Photosynthesis 652
  • Calvin's or C - 3 Cycle 652
  • Hatch and Slack's or C- 4 Cycle 652
○ CAM Plants
(Crassulacean Acid Metabolism Plants) 654
○ Law of Limiting Factors 654
○ Warburg's Effect 654
○ CO_2 Compensation Point 655
○ Factors Affecting Photosynthesis 655
○ Bacterial Photosynthesis 655
○ Chemosynthesis 656
○ Multiple Choice Questions 657
○ Answers 671
○ Explanation of Selected Questions 672

24. PLANT PHYSIOLOGY (IV) 673–694
○ Respiration 673
— General Characters 673
— Aerobic and Anaerobic Respiration 673
— Protoplasmic and Floating Respiration 673
○ Mechanism of Respiration 674
— Glycolysis 674
— Krebs' Cycle 675
— Terminal Oxidation 676
— Pentose Phosphate Pathway 677
— 38 or 36 ATP Molecules Produced in Oxidation of One mol. of Glucose Molecule 677
— Respiratory Quotient (R.Q.) 678
— Factors Affecting Respiration 678
— Light Compensation Point 678
— Pasteur's Effect 679
— Photorespiration 679
— Differences between Photorespiration and Normal (Dark) Respiration 679
— Glyoxylate Cycle 679
○ Translocation of Organic Food or Solutes 680
— General Characters 680
— Directions of Translocation of Solutes 680
— Path of Translocation of Solutes 680
— Mechanism of Translocation of Solutes 680
— Factors Affecting Translocation of Solutes 681
○ Multiple Choice Questions 682
○ Answers 693
○ Explanation of Selected Questions 694

25. PLANT PHYSIOLOGY (V) 695–724
○ Special Modes of Nutrition 695
— Saprophytes 695
— Symbiotic Plants 695
— Parasites 695
— Insectivorous Plants 696
○ Physiology of Flowering 696
— Photoperiodism 696
— Vernalization 697
○ Growth 698
— Phases of Growth 698
— Course of Growth 698
— Measurement of Growth 698
○ Growth Hormones 698
— Auxins 698
— Gibberellins 699
— Cytokinins 700
— Ethylene 700
— Abscisic Acid 701
— Morphactins 701
— Wound Hormone 701
○ Plant Movements 701
— Movements of Locomotion 702
  • Autonomic Movements of Locomotion 702
  • Induced Movements of Locomotion or Paratonic Movements 702
— Movements of Curvature 702
  • Autonomic Movements of Curvature 702
  • Induced Movements of Curvature Paratonic movements of Curvature 702
— Tropic Movements 702
— Nastic Movements 703
○ Multiple Choice Questions 704
○ Answers 723
○ Explanation of Selected Questions 724
☐ **Test Paper – Unit - 7** **725**
— Answers 726
☐ **Assertion and Reason Type Questions** **727**
— Answers 728

UNIT 8

13

26. ECOLOGY 731–789
○ Introduction 731
○ Ecology in India 731
○ Some Important Ecological Terms 731
○ Ecological Factors 734
— Climatic Factors 734
— Topographic Factors 737
— Edaphic Factors 737
— Biotic Factors 740
○ Ecosystem 741
— Types 741
— Structure and Function 741
— Ecological Pyramids 742
— Food-Chains 743
— Food Web 744
— Energy Flow in Ecosystem 744

— Productivity of Ecosystems 744
— Ecological Efficiencies 745
— Biogeochemical Cycles 745
— Major Biomes 747
○ Water Ecological Adaptations 748
— Hydrophytes 749
— Xerophytes 749
— Mesophytes 750
— Halophytes 750
○ Ecological Succession 750
○ Ecological Indicators 751
○ Soil Erosion and Soil Conservation 752
○ Pollution 753
○ Natural Resources 757
○ Biodiversity 757
○ Zonation in a Fresh Water Body (Lake) 759
○ Some Other Points to Remember 759
○ Multiple Choice Questions 760
○ Answers 787
○ Explanation of Selected Questions 789
☐ Test Paper – Unit - 8 790
— Answers 791
☐ Assertion and Reason Type Questions 792
— Answers 793

UNIT 9

27. APPLICATIONS OF BIOLOGY 797–839
○ Pesticides and Biological Pest Control 797
○ Biofertilizers 799
○ Domestication of Plants and Crop Plants Improvement 799
○ Transgenic Plants / Crops 803
○ Genetically Modified Foods 804
○ Genetic Conservation 805
○ New and Under-Utilized Crops 806
○ Bioenergy 807
○ Biotechnology 808
○ Biopatent 811
○ Biopiracy 812
○ Biotechnology and Sustainable Agriculture 812
○ Bio-War 813
○ Multiple Choice Questions 815
○ Answers 837
○ Explanation of Selected Questions 839
☐ Test Paper – Unit - 9 840
— Answers 842
☐ Assertion and Reason Type Questions 843
— Answers 844
SELF EVALUATION TESTS 845–864
○ Test - I 845
○ Answers 848
○ Test - II 849
○ Answers 852
○ Test - III 853
○ Answers 856
○ Test - IV 857
○ Answers 860
○ Test - V 861
○ Answers 864
IMPORTANT DISCOVERIES OF SOME SCIENTISTS I–V

UNIT-1

- General Introduction
- Classification and Diversity of Plant Kingdom
- Test Paper—Unit-1
- Assertion-Reason Type Questions—Unit-1

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الحافظ

بسم اللہ الرحمٰن الرحیم ○

1

General Introduction

- Nature and scope of Biology
- Characters of living organisms
- Differences between plants and animals
- Branches of Botany and famous workers associated with them
- Some famous Botanical Research Centres, Institutes and Gardens
- Units of measurements in Biology

BIOLOGY

Biology is the discipline which deals with the study of living forms or Biology is the science of life.

- The term 'Biology' has its origin from two Greek words: *Bios* (life) and *logos* (discourse or study), *i.e.*, study of life. Biology is also known as **'Life Science'** or **'Bioscience'**.
- As the Greek naturalist Aristotle (384–322 B.C.) made the first major biological studies, so he is rightly known as **'Father of Biology'**.
- The term 'Biology' was first used in 1802 by **Jean Baptiste de Lamarck** in France and G. **Treviranus** in Germany.
- Biology is generally called a **science of exceptions** because as against physical sciences, there are very few universal principles and laws in biology and living organisms show numerous variations and exceptions.
- There are two major forms of living organisms: Plants and animals and thus the two main branches of biology are:
  - (a) **Zoology** (Greek : *Zoon*–animal + *logos*–study), *i.e.*, study of animals.
  - (b) **Botany** (Greek : *Botane*–herb), *i.e.*, study of plants. The word *Botane* has its immediate origin from another Greek word, *Boskein*, grazing.

Botane = herb.

- Botany is also known as **'Phytology'**. → Study of Plants
  The Greek botanist **Theophrastus** (370–285 B.C.), a student of Aristotle, first described about 500 plants of food and medicinal value and other economic uses with some morphological characters, especially **habit**—herbs, shrubs, trees and annuals, biennials and perennials in his historic book, *'Historia Plantarum'* and he is known as **'Father of Botany'**.
- **William Roxburgh**—'Father of Indian Botany'.
- *'Historia Plantarum'* written by Theophrastus is considered to be the **oldest available literature** in the field of Botany.
- **Pliny the Elder** (28–79 A.D.) mentioned over 1000 plants of economic use in his book *'Historia Naturalis'*.
- *'Materia Medica'* another ancient book was written by another Greek, **Dioscorides**, which included information about drug plants.

CHARACTERS OF LIVING ORGANISMS

There is no clear cut definition of life as life is mysterious. But there are following characters by which living organisms can be distinguished from non-living:

1. **Protoplasm:** Life is not possible without protoplasm which is the living substance of the cell. All vital activities are performed in protoplasm and thus **J. Huxley** called it as 'Physical basis of life'. Protoplasm is the complex mixture of several chemical components in definite proportions.
2. **Cellular structure:** All living organisms are made of characteristic structural units called **cells**. An organism may be unicellular or multicellular. The term 'cell' was first used by **Robert Hooke** (1665).
3. **Life cycle:** All living beings follow a definite life cycle which comprises of (a) birth, (b) growth, (c) reproduction, (d) old age and (e) death.
4. **Respiration:** Living organisms respire continuously day and night and respiration involves taking in of O_2 and giving out of CO_2. Respiration is an oxidative, catabolic, energy releasing (exothermic) process in which energy is released by oxidation of food materials. (Food—any substance which releases energy after oxidation.) General reaction of respiration is:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 673 \text{ kcal.}$$

(Now considered to be 686 kcal.)

But, actually this mechanism is not so simple.

5. **Metabolism:** Sum total of all chemical activities of the cell, which are responsible for growth, maintenance and repair, constitute **metabolism**. Metabolic processes are of two types:
   - (a) Anabolic processes or Synthetic or Constructive processes (Anabolism)—In which, simple substances unite to form more complex substances.
   - (b) Catabolic processes or Destructive processes (Catabolism)—In which complex substances break down into

simple substances to release energy. Both these processes are independent.

- Metabolism = Anabolism + Catabolism.

6. **Growth and development:** Every living organism shows growth and development.
   - Growth is permanent (irreversible) change in size and dimensions associated with increase in dry matter. Or, Growth is the end product of **'successful metabolism'** (Anabolic processes more than Catabolic processes).
     Development: When growth is accompanied with differentiation, it is called development.
   - Growth is **quantitative** change only, whereas development is both **quantitative** and **qualitative** change.
7. **Nutrition:** All living organisms require nutrition, *i.e.*, supply of food. Living organisms are either **autotrophic** in their mode of nutrition, *i.e.*, make their own food or **heterotrophic**, *i.e.*, take up prepared food.
   - Heterotrophic mode of nutrition may be **saprophytic** (*i.e.*, from dead organic matter) or **parasitic** (*i.e.*, from living host).
8. **Reproduction:** Living organisms have the capacity to produce young ones of their own kind. Reproduction methods may be **vegetative, asexual or sexual.**
9. **Irritability or Sensitivity:** The phenomenon of responding to external stimuli, like temperature, light, etc., is called **irritability** and it is characteristic of protoplasm.
10. **Movements:** Movements are considered to be common sign of life. Movements are more pronounced in animals, *i.e.*, they move from one place to another (locomotion), whereas plants show movements of variations in their organs.
    - Movements in living organisms may be **spontaneous** or **induced.**
11. **Excretion:** All living organisms have capacity to throw out their waste products formed during metabolism.
12. **Healing:** Living organisms have the capacity to keep their bodies healthy by healing up of wounds or injured portions.

DIFFERENCES BETWEEN PLANTS AND ANIMALS

Differences between two main types of living organisms, *i.e.*, plants and animals are as follows:

S. No.	Characters	Plants	Animals
1.	Growth	(a) Growth continues upto end of life. (b) Growth is localized, *i.e.*, restricted to specialized cells at special places (meristems)—apical meristem, lateral meristem, etc.	(a) Growth stops after a certain stage. (b) Growth is diffused, *i.e.*, occurs all over the body.
2.	Cell Wall	Rigid cell wall generally made of cellulose forms the outermost envelope of the cell. Inner to the cell wall is present the cell membrane.	No cell wall and covering of cell is cell membrane or plasma membrane.
3.	Chlorophyll	Except fungi and total parasites, all the plants possess a green pigment mostly in leaves called chlorophyll.	Chlorophyll absent.
4.	Mode of nutrition	Due to presence of chlorophyll, plants are generally autotrophic in their mode of nutrition, *i.e.*, can manufacture their own food.	**Heterotrophic** in their mode of nutrition, *i.e.*, get ready made food.
5.	Photosynthesis	Green plants have the capacity to convert radiant energy of sun into chemical form of energy or green plants photosynthesize to form organic food from CO_2 and H_2O in presence of sunlight.	No photosynthesis.
6.	Movements	Movement is slow in plants and they show movements of curvature or variations of their own organs.	Movements obvious in animals and they move from one place to another (movements of locomotion).
7.	Absorption of minerals or Mineral nutrition	Plants absorb minerals from soil in the form of liquid or solution, *i.e.*, **Holophytic.**	Excepting a few, all animals obtain solid food, *i.e.*, **Holozoic.**
8.	Excretory system	Not so developed in plants. Waste products are transported to leaves or bark, which fall down.	Excretory system well developed.
9.	Centrosome	This structure or organelle is absent in plant cells (except some algae and fungi).	It is generally present adjacent to nucleus and helps in cell division.
10.	Vacuole	Generally a single large, central vacuole is present in plant cells, filled with cell sap.	Large, central vacuole absent in animal cells. Although, there may be many small vacuoles.
11.	Lysosome	Mostly absent.	Present.
12.	Cytokinesis	Cytokinesis by 'cell plate' method.	By 'cell furrow' method.

BRANCHES OF BOTANY AND FAMOUS WORKERS ASSOCIATED WITH THEM

(I) Main branches

1. **Cytology** (*Kytos*-cell + *logos*-study): Study of cell structure and function.
   - **Robert Hooke**—Father of Cytology.
   - **Swanson**—Father of Modern Cytology.
   - **Prof. A.K. Sharma** (Kolkata)—Famous Indian cytologist. He developed new techniques for the study of the physical and chemical nature of chromosomes including **Orcein banding** for repetitive DNA analysis. He also gave the concept of dynamic DNA and reported variations in chemical composition of chromosomes during differentiation, organogenesis and reproduction phenomena. He got 'Padma Bhushan' in 1983.
2. **Embryology:** Study of events which lead to the development of embryo or study of processes which occur during reproduction of plants.
   - **Prof. P. Maheshwari** (1904–1966, Delhi University)—Famous Indian embryologist. He was elected as Fellow of Royal Society of London (F.R.S.) in 1965 for his significant contributions. He is author of a famous book, '*An Introduction to Embryology of Angiosperms*' (1950). He also made a critical review of embryo sacs in angiosperms.
3. **Morphology** (*Morphe*-form + *logos*-study): Branch dealing with forms and features of different plant organs.
   (a) **External morphology**—External forms and features.
   (b) **Internal morphology**—Internal features.
      (i) **Anatomy** (*Ana*-asunder + *tamnein*-to cut): Study of internal structures of the plants after cutting the sections.
      - **N. Grew**—'Father of Plant Anatomy'.
      (ii) **Histology** (*Histos*-tissue + *logos*-study): Study of detailed structures of plant tissues as revealed by microscope.
      - **Prof. V. Puri**—Famous Indian morphologist.
4. **Morphogenesis** (*Morphe* - form + *genesis* - formation): Study of formation of organs during development.
5. **Ecology** (*Oikos*-house or dwelling + *logos*-study): Study of organisms at their home or study of reciprocal relationship of organisms and their environment.
   - **Dudgeon** (1921)—Started ecological studies in India.
   - **Prof. R. Mishra**—Famous ecologist of India, rightly known as 'Father of Indian Ecology'.
6. **Plant physiology** (*Physis*-nature of life): Study of various functional aspects of plants, like metabolism, growth, movement, respiration, etc.
   - **Stephen Hales**—'Father of Plant Physiology'.
   - **Sir J.C. Bose, J.J. Chinoy, K.K. Nanda and G.S. Sirohi**—Famous Indian plant physiologists.
   - **Prof. G.S. Sirohi**—First Indian to reach Antarctica.
7. **Genetics:** Study of heredity and variations.
   - **Gregor Johann Mendel**—'Father of Genetics'.
   - **T.H. Morgan**—'Father of Modern Genetics'.
   - **Prof. R.P. Roy** (Patna University) is a famous Indian cytogeneticist. He made genome analysis of *Aegilops* in relation to the origin and evolution of bread wheat. Further, he studied sex determination mechanism in *Coccinia indica* (Family Cucurbitaceae) with the discovery of sex chromosomes (X and Y) in it.
8. **Plant taxonomy or Plant systematics** (*Taxis*, arrangement): Branch dealing with identification, nomenclature and classification of plants.
   - **Carolus Linnaeus**—'Father of Taxonomy or Modern Botany'.
   - **H. Santapau**—'Father of Indian Taxonomy'.
9. **Palaeobotany** (*Palaios*-ancient): Study of fossil plants.
   - **Prof. Birbal Sahni and Prof. D.D. Pant**—Famous Indian palaeobotanists. **Prof. Birbal Sahni** (1891–1949) is called 'Father of Indian Palaeobotany' and his most significant contribution is the discovery of a fossil class of gymnosperms of Jurassic period called **Pentoxylae** from Nipania Chert in Raj Mahal hills of Bihar. He established an institute of palaeobotanical studies in Lucknow (U.P.) in 1946, which is nowadays known as 'Birbal Sahni Institute of Palaeobotany'.
10. **Evolution:** Origin of living beings and their gradual changes.
11. **Phytogeography or Plant geography:** Study of plants in respect of their distribution.
12. **Economic botany:** Study of useful plants and their products or plants in relation to human welfare.

(II) Some particular or specific branches

1. **Algology or Phycology:** Study of algae.
   - **F.E. Fritsch**—Famous international algologist.
   - **M.O.P. Iyengar, Desikachary, R.N. Singh and Y. Bhardwaj**—Famous Indian Algologists or Phycologists.
   - **M.O.P. Iyengar**—'Father of Modern Algology in India'.
2. **Mycology or Mycetology:** Study of fungi.
   - **Micheli**—'Father of Mycology'.
   - **E.J. Butler**—'Father of Indian Mycology'.
3. **Bryology:** Study of Bryophytes.
   - **Hedwig**—'Father of Bryology'.
   - **Prof. S.R. Kashyap** (1882–1934)—Famous Indian bryologist and is called 'Father of Indian Bryology'. Prof. Kashyap is author of a famous book, '*Liverworts of the Western Himalayas and Punjab Plains*' in two volumes. He discovered four new genera of Bryophytes—*Aitchisoniella, Stephensoniella, Sauchia* and *Sewardiella*. Prof. Kashyap was the pioneer to start M.Sc. classes in Botany in India (at Government College, Lahore).
4. **Pteridology:** Study of pteridophytes.
5. **Bacteriology:** Study of bacteria.
   - **Anton van Leeuwenhoek**—'Father of Bacteriology'.
6. **Virology:** Study of viruses.
7. **Pomology:** Study of fruits and fruit yielding plants.
8. **Palynology:** Study of pollen grains.

- **P.K.K. Nair**—Famous Indian palynologist.

9. **Anthology:** Study of flowers.
10. **Agrostology:** Study of grasses or lawns.
11. **Dendrology or Xylology:** Study of shrubs and trees.
12. **Dendrochronology:** Determination of age of the trees by counting annual rings.
    - Glock gave the concept of **'Tree Calendars'**. These are of great help in predicting or in finding the events that took place in the past.
13. **Exobiology:** Study of living organisms of outer space or other planets.
14. **Edaphology or Pedology:** Study of soils.
15. **Ethanobotany:** Study of plants of tribal or primitive people's use.
16. **Biochemistry:** Branch dealing with chemical nature and chemical behaviour of living matter.
17. **Biophysics:** Principles of physics applied to biology.
18. **Biometrics:** Applying principles of mathematics and statistics to biological data.
19. **Lichenology:** Study of lichens.
20. **Microbiology:** Study of microscopic organisms.
    - Louis Pasteur—'Father of Microbiology'.
21. **Phenology:** Study of seasonal changes in plants.
22. **Photobiology:** Study of light effects on living organisms.
23. **Serology:** Serum and antigen-antibody interactions.
24. **Spermology:** Study of seeds.
25. **Toxicology:** Toxins production and their effects.
26. **Trophology:** Study of nutrition.
27. **Xylotomy:** Study of wood or xylem vessels.

(III) Some applied branches

1. **Plant pathology or Phytopathology:** Study of plant diseases, their causes, symptoms and methods of control.
    - E.J. Butler—'Father of Indian Plant Pathology.'
    - K.C. Mehta (1892–1950)—Famous Indian plant pathologist who studied **'Annual recurrence of wheat rust in the plains of India'**. He was of the opinion that oversummering uredospores of rust on self-sown wheat plants and some grasses in the hills are a source of infection for wheat in the next season. He was awarded D.Sc. degree by Cambridge University for his work on black rust disease of wheat. Prof. Mehta was initially Professor of Botany in Agra College, Agra and then he was appointed Principal of the same college.
2. **Plant breeding:** Production and development of new high yielding and disease resistant varieties of different crop plants.
    - N. Borlaug—Famous Mexican wheat breeder, who was awarded Nobel Peace Prize (1970) for production of various dwarf varieties of wheat like Sonora-64, Lerma rojo, etc.
    - Dr. M.S. Swaminathan—Famous wheat breeder of India, who developed 'Sharbati Sonora' variety of wheat by mutation breeding, which is responsible for 'Green revolution' in India. He is called as the 'Founder of Radiation Genetics'. He held the position of Director General of ICAR (1972–1980) and then the post of Director General of IRRI, Manila (Philippines). He is recipient of Padmashree (1967), Padma Bhushan (1972) and Raman-Magsaysay Award (1971).
3. **Agriculture:** Study of cultivation of plants for human use.
4. **Horticulture:** Dealing with cultivation of garden plants for flowers, vegetables and fruits.
    (a) **Olericulture:** Cultivation of vegetables.
    (b) **Floriculture:** Cultivation of flower yielding plants.
5. **Agronomy:** Dealing with cultivation of field crops for food and industry.
6. **Arboriculture:** Cultivation of ornamental trees and shrubs.
7. **Silviculture or Forestry:** Study and utilization of forests and forest products for economic purposes.
8. **Pharmacognosy:** Study of medicinal and drug plants.
    - Hippocrates—'Father of medicine'.
9. **Pharmacology:** Study of action of drugs.
10. **Cryobiology:** Preservation of germplasm by freezed-dry storage or life at low temperatures.
11. **Biotechnology:** Use of living organisms or substances obtained from them for industrial purposes.
12. **Genetic engineering:** Gene manipulations for production of organisms with new characters.
    - Paul Berg—'Father of Genetic Engineering'.
13. **Tissue culture:** One of the latest technologies for improvement of plants, which is based on totipotent nature of plant cell or 'Concept of totipotency', *i.e.*, each and every plant cell has inherent capacity to develop into complete plant. This concept of totipotency was given by **Haberlandt** (1902).
14. **Agroforestry:** The branch dealing with mode of land use in which crops, multipurpose shrubs and trees are cultivated to get useful products like fodder, fuel and timber, etc., and to stabilize soil.
15. **Bonsai:** Art of growing dwarf plants.
16. **Topiary:** Art of pruning plants so as to obtain desired shape.

(IV) Some other branches

1. **Aerobiology:** Study of organisms present in air.
2. **Actinobiology:** Study of effects of radiations on living beings.
3. **Karyology:** Study of nucleus.
4. **Molecular biology:** Study of physico-chemical organization of biomolecules.
5. **Limnology:** Study of freshwater ecology or life in freshwater.
6. **Oncology:** Study of tumours.
7. **Parasitology:** Study of parasitism.
8. **Teratology:** Study of abnormal embryonic development.
9. **Toxicology:** Study of poisonous effects on plants (organisms).
10. **Gerontology:** Study of process of ageing.

SOME FAMOUS RESEARCH CENTRES, INSTITUTES AND GARDENS

(A) International

1. Royal Botanical Garden, Kew, England.
   - Largest botanical garden in the world and its herbarium is also the largest in the world, having 6,000,000 (6 million) specimens.
2. CIAT (International Centre for Tropical Agriculture).
   - Located at Palmira, Columbia.
3. CIP (International Centre for Potato).
   - Located at Lima, Peru.
4. ICARDA (International Centre for Agricultural Research in Dry Areas).
   - Located at Allepo, Syria.
5. ICRISAT (International Centre for Agricultural Research for Semi Arid Tropics).
   - Located at Patencheru (Hyderabad).
6. IRRI (International Rice Research Institute).
   - Located at Manila, Philippines.
7. IPGRI (International Plant Genetic Resources Institute). Earlier it was named as IBPGR (International Board for Plant Genetic Resources).
   - Located at Rome, Italy.

(B) National

1. Indian Botanical Garden, Kolkata.
   - Largest botanical garden in India and its herbarium is the largest in India, having 1 million (1,000,000) specimens.
2. National Botanical Garden, Lucknow (U.P.).
   - Nowadays known as National Botanical Research Institute (NBRI).
3. BSI—Botanical Survey of India.
   - BSI has its head quarters at Howrah (Kolkata).
   - BSI started working in 1890 and is connected with plant exploration and writing up of regional flora and also preparation of flora of India.
4. CIMAP (Central Institute of Medicinal and Aromatic Plants) at Lucknow (U.P.).
   - Also called CIMPO (Central Indian Medicinal Plants Organization).
5. IARI (Indian Agricultural Research Institute) or Pusa Institute.
   - Located at New Delhi.
   - It was initially established at village Pusa in Darbhanga Distt. of Bihar in 1905 under the name **Imperial Agricultural Research Institute.** After a severe earthquake, this Institute was shifted to New Delhi in 1936 under the same name. But after independence, it was renamed as **Indian Agricultural Research Institute.**
   - IARI, New Delhi is popularly known as **Pusa Institute** after the name of village **Pusa** in Bihar, where it was first established.
6. FRI—Forest Research Institute—at **Dehradun** (Uttaranchal).
   - Established in 1906 under the name Imperial Forest Research Institute (IFRI), but after independence, its name was changed to FRI.
   - This institute is connected with researches on different aspects of forest trees and it also provides training to forest officers.
7. Birbal Sahni Institute of Palaeobotany—at Lucknow (U.P.).
8. CAZRI—Central Arid Zone Research Institute—at Jodhpur (Rajasthan).
9. CDRI—Central Drug Research Institute—at Lucknow (U.P.).
10. CPRI—Central Potato Research Institute—at Shimla (H.P.).
11. CRRI—Central Rice Research Institute—at Cuttack (Orissa).
12. CFTRI—Central Food Technology Research Institute—at Mysore.
13. CJTRI—Central Jute Technology Research Institute—at Kolkata (W. Bengal).
14. CTRI—Central Tobacco Research Institute—at Rajah Mundry (A.P.).
15. CSSRI—Central Soil Salinity Research Institute—at Karnal (Haryana).
16. IISR—Indian Institute of Sugar Cane Research—at Lucknow (U.P.).
17. ITRC—Industrial Toxicology Research Institute—at Lucknow (U.P.).
18. CPHERI—Central Public Health Engineering Research Institute—at Nagpur (Maharashtra).
19. NEERI—National Environmental Engineering Research Institute—at Nagpur (Maharashtra).
20. NIO—National Institute of Oceanography—at Dauna Paula (Goa).
21. IIST—Indian Institute of Sugar Technology—at Kanpur (U.P.).
22. IGFRI—Indian Grassland and Fodder Research Institute—at Jhansi (U.P.).
23. SBI—Sugar Cane Breeding Institute—at Coimbatore (Tamil Nadu).
24. ICAR—Indian Council of Agricultural Research—at New Delhi.
    - All Agricultural Universities and Research Institutes are under its supervision.
25. CSIR—Council of Scientific and Industrial Research—at New Delhi.
26. NBPGR—National Bureau of Plant Genetic Resources—at New Delhi.

1cm = 10mm
1mm = 10 cm

UNITS OF MEASUREMENTS IN BIOLOGY

1 μ (micron) or 1 μm (micrometre) = 10^{-3} mm = 10^{-4} cm = 10^{-6} m

1 mμ (millimicron) or 1 nm (nanometre) = 10^{-3} μ or μm = 10^{-6} mm = 10^{-7} cm = 10^{-9} m

1 Å (Angstrom) = 10^{-1} nm or mμ = 10^{-4} μ or μm = 10^{-7} mm = 10^{-8} cm = 10^{-10} m

1 Picometre = 10^{-12} m

1 Femtometre = 10^{-15} m

1 Attometre = 10^{-18} m

1cm = 10mm
[illegible] 10Å

MULTIPLE CHOICE QUESTIONS

1. The term Biology was coined by:
(a) Linnaeus (b) Aristotle
(c) Theophrastus [✓ (d) Lamarck]

2. Who is known as the 'Father of Botany'? **(MPPMT 1999; Raj. PMT 2001)**
(a) Lamarck (b) Aristotle
[✓ (c) Theophrastus] (d) Tippo

3. Biology is:
(a) Study of uniformity behind diversity in living organisms
[✓ (b) Study of all living organisms]
(c) Study of growth and differentiation in living organisms
(d) Study of life as recorded by fossils

4. The word Botany has its immediate origin from:
(a) Boskein (b) Bous
[✓ (c) Botane] (d) Cattle

5. The sphere of Botany is:
[✓ (a) Study of everything about plants]
(b) The description of all plants
(c) Study of uses of plants
(d) Classification and nomenclature of plants

6. Physical basis of life is:
(a) Nucleus (b) The cell
[✓ (c) Protoplasm] (d) Food

7. Aristotle is known as:
(a) Botanist (b) Zoologist
(c) Founder of Botany [✓ (d) Father of Biology]

8. The most peculiar feature shown by all living organisms is:
(a) Excretion (b) Autotrophic nature
[✓ (c) Respiration] (d) Cellular structure

*9. The degradative phase of life cycle is:
(a) Ageing [✓ (b) Senescence]
(c) Maturity (d) None of these

10. Who said, 'Protoplasm is the physical basis of life'?
(a) Dujardin (b) Purkinje
[✓ (c) Huxley] (d) Schleiden

11. The term 'Protoplasm' was given by:
(a) Von Mohl [✓ (b) Purkinje]
(c) Max Schultz (d) None of these

12. Bacteria were discovered by:
(a) J. Sachs (b) Mendel
(c) Lister [✓ (d) Leeuwenhoek]

13. The plants are distinct from animals in having: **(St. Jones 2002)**
(a) Locomotion (b) Centromere
[✓ (c) Localized growth] (d) Metabolism

14. The main difference between non-living and living is:
(a) In size
(b) In movement and growth
[✓ (c) In presence of protoplasm]
(d) None of the above

15. Plants are like animals in that they:
(a) Respire during day only
(b) Respire during night only
[✓ (c) Respire during day and night]
(d) Respire when required

16. Growth continues upto death in:
[✓ (a) Plants] (b) Animals
(c) Both (a) and (b) (d) None of these

*17. Banana is a:
[✓ (a) Herb] (b) Shrub
(c) Tree (d) Undershrub

18. Study of light effects on living organisms is:
(a) Photoperiodism (b) Photomorphogenesis
(c) Vernalization [✓ (d) Photobiology]

19. A botanist studying distribution of tissues in a stem is doing work on:
(a) Ecology (b) Anatomy
[✓ (c) Histology] (d) Cytology

20. The branch of Botany concerned with living activity and function:
(a) Ecology [✓ (b) Physiology]
(c) Cytology (d) Morphology

21. Branch of Botany dealing with distribution of plants on earth's surface is called:
(a) Ecology (b) Phytology
[✓ (c) Phytogeography] (d) Phytosociology

*22. One of the following branches includes the study of both plants and animals:
[✓ (a) Microbiology] (b) Virology
(c) Horticulture (d) Mycology

23. The science that deals with rearing and proper management of forest trees is called:
[✓ (a) Silviculture] (b) Sericulture
(c) Pisciculture (d) Arboriculture

24. Pedology is the science of:
(a) Rocks (b) Diseases
[✓ (c) Soil] (d) Humus

25. Agrostology is the study of:
(a) Crops [✓ (b) Lawns]
(c) Garden plants (d) Oil seeds

26. Exobiology is the study of: **(B.V. Pune 2003)**
(a) Terrestrial organisms (b) Life in air
[✓ (c) Life on other planets] (d) Exodermis

27. Famous Indian Morphologist is:
(a) Santapau (b) V. Puri
(c) K.K. Nanda (d) P. Maheshwari

28. The science of vegetable culture is:
(a) Agriculture (b) Horticulture
[✓ (c) Olericulture] (d) Floriculture

29. National Botanical Garden is situated at:
(a) Kanpur (b) Delhi
(c) Kolkata (d) Lucknow

30. The largest herbarium in the world is in:
[✓ (a) Kew, England] (b) Paris
(c) Mexico (d) Berlin

31. Birbal Sahni Institute of Palaeobotany is at: **(BHU 2002)**
(a) Kolkata (b) Jodhpur
(c) Lucknow (d) Mumbai

32. S.R. Kashyap was a famous Indian:
(a) Phycologist (b) Microbiologist
(c) Bryologist (d) Pteridologist

33. Anthology is the study of: (DPMT 1992)
(a) Anthers [✓ (b) Flowers]
(c) Fruits (d) Vegetables

34. Cryobiology is the science of:
[✓ (a) Freezed-dry storage of germplasm]
(b) Warm-dry storage of germplasm
(c) Small organisms
(d) None of the above

35. Sonora-64 variety of wheat was developed by:
(a) Khorana (b) Swaminathan
(c) Borlaug (d) B.P. Pal

36. Mycetology (Mycology) is the study of:
(a) Algae (b) Thallophyta
[✓ (c) Fungi] (d) Diseases

37. Study and utilization of forests and their products:
(a) Sericulture [✓ (b) Silviculture]
(c) Tissue culture (d) None of these

38. 'Tree Calendars' were developed by:
(a) K.A. Chaudhary (b) K.C. Mehta
(c) Glock (d) None of these

39. The plants of tribal use are studied under:
(a) Tribal botany (b) Cryobotany
[✓ (c) Ethnobotany] (d) Actinobotany

40. The concept of 'Totipotency' was given by:
(a) Steward (b) P. Maheshwari
(c) V. Puri [✓ (d) Haberlandt]

41. Spermology deals with the study of:
[✓ (a) Seeds] (b) Leaves
(c) Fruits (d) Pollen grains

42. Central Drug Research Institute is located at:
(a) Lucknow (b) Mumbai
(c) Jammu (d) Kolkata

43. Who is the 'Father of Medicine'?
(a) Aristotle (b) Theophrastus
[✓ (c) Hippocrates] (d) Charak

44. Palynology is the study of: (DPMT 1997)
(a) Grasses [✓ (b) Pollen grains]
(c) Fossils (d) None of these

45. M.O.P. Iyengar was a famous:
(a) Mycologist (b) Phycologist
(c) Pteridologist (d) Pedologist

46. Who is the 'Father of Plant Physiology'?
(a) Krebs (b) Dixon
[✓ (c) Stephen Hales] (d) Von Mohl

47. Who is known as 'Father of Indian Mycology and Plant Pathology'?
(a) Mundkar (b) Bulter
(c) K.C. Mehta (d) Sadasivan

48. R. Mishra is a famous:
(a) Physiologist (b) Morphologist
(c) Ecologist (d) Embryologist

49. Person responsible for Green revolution in India is:
(a) Borlaug (b) B.P. Pal
(c) M.S. Swaminathan (d) Maheshwari

50. IARI (Pusa Institute) was initially set-up in:
(a) Bihar (b) U.P.
(c) Bengal (d) Orissa

51. A paper was published in a journal of flora of Distt. Meerut. In which branch of Botany should this paper be placed?
(a) Morphology [✓ (b) Taxonomy]
(c) Evolution (d) Phytogeography

52. Name the branch of Botany, which is involved with isolation and fusion of cells *in vitro*:
(a) Olericulture (b) Floriculture
[✓ (c) Tissue culture] (d) Arboriculture

53. 1 Angstrom unit (1 Å) is equal to: (CBSE 1992)
(a) 0.00001 µm [✓ (b) 0.0001 µm] 10^{-4}
(c) 0.001 µm (d) 0.01 µm

54. One mµ (millimicron) is equal to: (CPMT 1992)
(a) 10^{-9} mm [✓ (b) 10^{-6} mm]
(c) 10^{-5} mm (d) 10^{-3} mm

55. What is the value of angstrom in metre? (CPMT 1993)
[✓ (a) 10^{-10} m] (b) 10^{-9} m
(c) 10^{-8} m (d) 10^{-5} m

56. Nanometre (nm) has another name:
[✓ (a) Millimicron (mµ)] (b) Micron (µ)
(c) Angstrom (Å) (d) Micrometre (µm)

57. One nanometre (1 nm) is equal to:
(a) 10^{-7} m [✓ (b) 10^{-9} m]
(c) 10^{-6} m (d) 10^{-3} m.

58. Name the management system, which deals with ecological principles, establishment, growth and reproduction of timber trees: (CMC, Vellore 1990)
[✓ (a) Silviculture] (b) Afforestation
(c) Horticulture (d) None of these

59. The branch of Botany dealing with interactions of organisms and the environment is known as:
(a) Phytogeography [✓ (b) Ecology]
(c) Physiology (d) Palaeobotany

60. Study of nucleus is known as:
(a) Neurology [✓ (b) Karyology]
(c) Mycology (d) Herpetology

61. The discipline dealing with study of inheritance is:
(a) Cytology (b) Evolution
[✓ (c) Genetics] (d) Anatomy

62. The branch dealing with study of cell structure is called as:
(a) Histology (b) Ecology
(c) Morphology [✓ (d) Cytology]

63. The study of immunological reactions occurring in th
blood is known as:
(a) Haematology (b) Biochemistry
[✓ (c) Serology] (d) Pathology

64. Application of statistical methods to the study of biologica
problems is called: (CPMT 1990
[✓ (a) Biometry] (b) Biophysics
(c) Chi-square (d) Nurture

65. Determination of age of trees by counting annual rings i
known as: (AIIMS 1992
(a) Chronology (b) Dendrology
[✓ (c) Dendrochronology] (d) Dendrochronologist

66. Study of interaction of antigens and antibodies is known as:
(a) Cryobiology (b) Serology
(c) Herpetology (d) Angiology

67. The branch concerned with the study of abnormal embryonic development is termed as: (AIIMS 1992)
(a) Gerantology (b) Teratology
(c) Embryology (d) None of these

68. The science of naming of plants is known as:
(a) Classification (b) Identification
(c) Nomenclature (d) Taxonomy

69. Forest Research Institute (F.R.I.) is located at: (MPPMT 2002)
(a) Lucknow (b) Dehradun
(c) Kolkata (d) Delhi

70. The branch dealing with the study of shrubs and trees is known as:
(a) Dendrology (b) Anthology
(c) Pomology (d) Palynology

71. The study of periodic phenomena in plants is known as:
(a) Dendrology (b) Anthology
(c) Dendrochronology (d) Phenology

72. Study of effects of radiation on living beings is known as:
(a) Actinobiology (b) Aerobiology
(c) Karyology (d) Oncology

73. The study of nuclear cytology is known as:
(a) Neurology (b) Mycology
(c) Rhinology (d) Karyology

74. Who is associated with the study of annual recurrence of wheat rust in India? (CBSE 1992)
(a) E.J. Butler (b) K.C. Mehta
(c) M.S. Swaminathan (d) M.O.P. Iyengar

75. Science dealing with structure and function of biomolecules is:
(a) Physiology (b) Cell biology
(c) Molecular biology (d) Microbiology

76. Study of micro-organisms in the space comes under: (BHU 1996)
(a) Phytogeography (b) Exobiology
(c) Anthology (d) Dendrology

77. The branch dealing with utilization of plant resources is: (AIIMS 1996)
(a) Agriculture (b) Economic botany
(c) Plant breeding (d) Horticulture

78. Olericulture is: (CET Chandigarh 1997)
(a) Study of fruits
(b) Study of cultivation of flowers
(c) Study of cultivation of vegetables
(d) Study of grasses

79. Genetics is the branch dealing with: (DPMT 1997)
(a) Study of development
(b) Study of heredity and variations
(c) Study of functional aspects
(d) None of the above

80. Art of growing dwarf trees is: (APMEE 1995; AFMC 2002)
(a) Bonsai (b) Horticulture
(c) Silviculture (d) Arboriculture

81. Which deals with establishment, growth and reproduction of timber trees? (CMC, Vellore 1990)
(a) Afforestation (b) Silviculture
(c) Horticulture (d) Agroforestry

82. Which pair is mismatched ? (Manipal 1995)
(a) Pedology—Soil science
(b) Physiology—Study of processes and functions of life
(c) Kinesiology—Study of fossils
(d) Limnology—Study of freshwater ecosystems

83. Employment of hereditary principles in the improvement of human race is: (CPMT 1991; Bihar PMT 1996)
(a) Euthenics (b) Eugenics
(c) Euphenics (d) Ethnology

84. Pedology is the: (Bihar CME Re-exam. 1997)
(a) Study of soil formation
(b) Formation of organic matter
(c) Study of forest
(d) Study of petrol

85. Which of the following is used to measure cell? (CPMT 1998)
(a) Nanometre (nm) (b) Angstrom (Å)
(c) Micrometre (μ) (d) Millimetre (mm)

86. Ethnobotany is related with: (CPMT 1998)
(a) Use of plants in old times
(b) Dispersal of plants
(c) Use of plants medicinally
(d) Development of plants

87. The name associated with mosses is: (CPMT 1998)
(a) Kashyap (b) Maheshwari
(c) Beadle (d) Swaminathan

*88. Study of plant and animal tissues outside the body in a glass tube is called: (CBSE 1990)
(a) *in vivo* (b) *in vitro*
(c) *de novo* (d) Innate

89. Biology is concerned with: (Rohtak PMT 1994)
(a) Organisms (b) Organic mass
(c) Biomass (d) DNA

90. A green pigment present in plants, which makes them autotrophic, is:
(a) Chloroplast (b) Carotenoid
(c) Chlorophyll (d) Anthocyanin

91. The smallest unit of measurement used in cell biology is:
(a) Micron (μ) (b) Nanometre (nm)
(c) Millimicron (mμ) (d) Angstrom (Å)

92. The oldest available literature in the field of botany is:
(a) *Historia Naturalis* (b) *Historia Plantarum*
(c) *Materia Medica* (d) *Species Plantarum*

93. Who is known as 'Father of Indian Botany'?
(a) Theophrastus (b) William Roxburgh
(c) Santapau (d) S.R. Kashyap

94. The final end product of successful metabolism is:
(a) Development (b) Growth
(c) Differentiation (d) Morphogenesis

95. One metre is equal to:
(a) 10^{-4} Å (b) 10^{-10} Å
(c) 10^{10} Å (d) 10^{12} Å

96. The processes in which complex substances break down into simple substances constitute:

(a) Metabolism
(b) Anabolism
[✓ (c) Catabolism]
(d) Commensalism

97. Study of formation of organs during development is called:

(a) Morphology
[✓ (b) Morphogenesis]
(c) Tissue culture
(d) Histology

98. Study of wood and xylem elements is known as:

(a) Dendrology
(b) Anatomy
(c) Histology
[✓ (d) Xylotomy]

99. Father of Genetic engineering is:

(a) Hedwig
[✓ (b) Paul Berg]
(c) H.G. Khorana
(d) Swanson

*100. Growing of complete plant from a cell is known as: (Manipal 2001)

(a) Totipotency
(b) Axenic culture
[✓ (c) Micropropagation]
(d) Clone formation

(CET Karnataka 2000)

101. NEERI is:

(a) National Ecological and Environmental Research Institute
[✓ (b) National Environmental Engineering Research Institute]
(c) National Ethological and Ecological Research Institute
(d) National Eugenics and Ecological Research Institute

102. Match the names of branches of Biology listed under column I with the field of study given under column II; choose the answer which gives the correct combination of alphabets of the two columns: (CET Karnataka 2001)

	Column I (Branch)		Column II (Field of study)
A	Palynology	e	Silkworms
B	Oncology	f	Pollens
C	Phycology	g	Cancer
D	Sericulture	h	Algae

(a) A = g, B = f, C = h, D = e
(b) A = h, B = g, C = f, D = e
[✓ (c) A = f, B = g, C = h, D = e]
(d) A = h, B = f, C = g, D = e

*103. At which research institute medicine regarding antivenom is made? [BCECE (P.T. Exam.) 2001]

(a) CDRI (Lucknow)
(b) AIIMS (Delhi)
(c) HRI (Mumbai)
(d) IRTC (Lucknow)

(Raj. PMT 2001)

104. Study of flowers is called:

(a) Agrostology
[✓ (b) Anthology (anthecology)]
(c) Spermology
(d) Malacology

(Pb. PMT 2000)

105. Study of ageing is known as:

(a) Palynology
[✓ (b) Gerontology]
(c) Genetics
(d) Speraelogy

(CET J&K 2002)

106. The full form of IPGRI is:

(a) Indian Plant Genetic Resources Institute
[✓ (b) International Plant Genetic Resources Institute]
(c) International Potato Genetic Resources Institute
(d) International Pine Genetic Resources Institute

107. Introduction of foreign genes for improving genotype is: (AIIMS 2002)

(a) Biotechnology
(b) Tissue culture
(c) Vernalization
[✓ (d) Genetic engineering]

108. Branch of botany connected with study of food, fibre and wood yielding plants is: (MPPMT 2002)

(a) Ethnobotany
(b) Palaeobotany
[✓ (c) Economic botany]
(d) Microbiology

109. The taxon Pentoxylae was reconstructed by: (EAMCET 2002)

(a) M.O.P. Iyengar
[✓ (b) Birbal Sahni]
(c) K.C. Mehta
(d) P. Maheshwari

110. National Environmental Engineering Research Institute (NEERI) is in: (Kerala PMT 2003)

(a) New Delhi
[✓ (b) Nagpur]
(c) Kolkata
(d) Chennai
(e) Bangalore

111. Which of the following chemical characteristics is not common to all living beings? (Manipal 2003)

(a) Ribosomes are the sites of protein synthesis
[✓ (b) Type of protein present in the body]
(c) Energy is stored by high phosphate bonds
(d) Similar triplet code for amino acids

(Manipal 2003)

112. Growth is:

(a) Synthesis of new protoplasm
(b) Increase in weight
(c) Increase in size
[✓ (d) All of the above]

113. The complete development of an organism is known as: (Manipal 2003)

(a) Parthenogenesis
[✓ (b) Ontogeny]
(c) Oogenesis
(d) Phylogeny

ANSWERS

1—d	2—c	3—b	4—c	5—a	6—c	7—d	8—c	9—b	10—c	11—b	12—d
13—c	14—c	15—c	16—a	17—a	18—d	19—c	20—b	21—c	22—a	23—a	24—c
25—b	26—c	27—b	28—c	29—d	30—a	31—c	32—c	33—b	34—a	35—c	36—c
37—b	38—c	39—c	40—d	41—a	42—a	43—c	44—b	45—b	46—c	47—b	48—c
49—c	50—a	51—b	52—c	53—b	54—b	55—a	56—a	57—b	58—a	59—b	60—b
61—c	62—d	63—c	64—a	65—c	66—b	67—b	68—c	69—b	70—a	71—d	72—a
73—d	74—b	75—c	76—b	77—b	78—c	79—b	80—a	81—b	82—c	83—b	84—a
85—c	86—a	87—a	88—b	89—a	90—c	91—d	92—b	93—b	94—b	95—c	96—c
97—b	98—d	99—b	100—c	101—b	102—c	103—c	104—b	105—b	106—b	107—d	108—c
109—b	110—b	111—b	112—d	113—b							

EXPLANATION OF SELECTED QUESTIONS (*)

9. Sum total of processes from birth to death is ageing and last degradative phase of ageing is called senescence.

17. Banana is one of the largest herbs as the stem is not lignified and pseudostem or shaft is made of overlapping leaf bases. Banana is also called herbaceous tree.

22. Micro-organisms include both plants and animals.

88. Study of tissues inside the body is called *in vivo* and outside the body is called *in vitro*, *e.g.*, isolation and fusion of cells is done *in vitro* (in tissue culture technique).

100. Propagation through tissue culture (culture of single or group of cells) is called micropropagation.

103. In Haffkine Research Institute (HRI), Parel, Mumbai, antivenom vaccines are prepared.

2

Classification and Diversity of Plant Kingdom

- Fundamental classifications: Eichler's, Tippo's, Whittaker's and Six kingdom classification
- Diversity in plants

CLASSIFICATION

There are a large number of plants in this universe differing from each other in form, structure and reproduction. The approximate number of known species in the plant kingdom is about 3,43,000 up-to-date.

- It is not possible to study this huge variety of plant species without arranging and dividing them into smaller groups and sub-groups.

This system of dividing and arranging the organisms into different groups, sub-groups on the basis of similarities and dissimilarities is known as '**Classification**'. The purpose of classification of living organisms is:

(a) To facilitate identification of unknown species.

(b) To help in knowing the relationships among different groups of organisms.

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(c) To evolve the origin and to trace the evolution of species.

- The classification of organisms comes under '**Taxonomy**' the term given by a French botanist **A.P. de Candolle**. Taxonomy includes identification, nomenclature and classification of individuals.

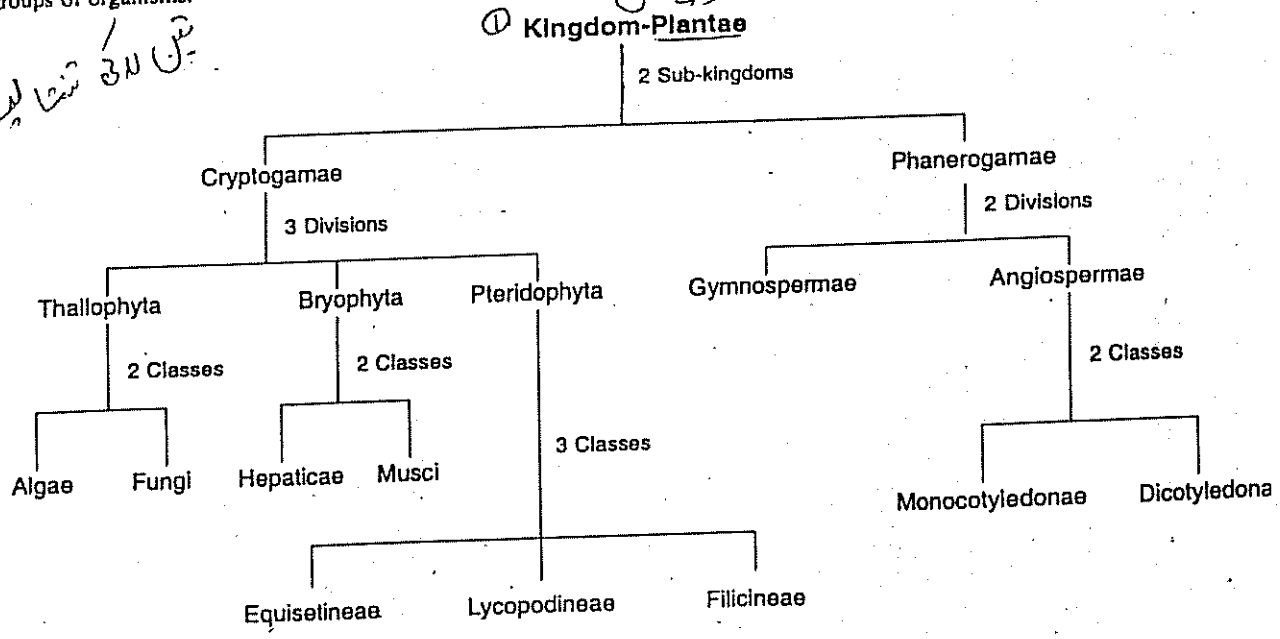
Here, we are presenting some fundamental classifications, s that readers may be given the basic ideas of different groups an sub-groups of plants. Some fundamental classifications are give below:

I. Eichler's classification

A Viennese worker, **A.W. Eichler** (1883) gave this classific tion in '*Syllabus der Vorlesungen uber Phanerogamen Kunde*'.

- According to this, the plant kingdom is divided as follow:

وینیس


① Kingdom-Plantae
2 Sub-kingdoms
Cryptogamae
Phanerogamae
3 Divisions
2 Divisions
Thallophyta
Bryophyta
Pteridophyta
Gymnospermae
Angiospermae
2 Classes
2 Classes
2 Classes
3 Classes
Algae
Fungi
Hepaticae
Musci
Monocotyledonae
Dicotyledona
Equisetineae
Lycopodineae
Filicineae

Characters of different groups

(A) Cryptogamae (Greek : *Kryptos*-hidden + *gamos*-marriage) or **Flowerless and seedless plants.**

The reproduction is by spores. Divided into 3 divisions:

(1) **Thallophyta:** (Greek : *Thallose*-a young shoot + *phyton*-plant) or here, the plant body is not differentiated into true roots, stem and leaves. Further, these are **non-vascular** plants (without xylem and phloem); sex organs are generally **unicellular** and **non-jacketed** and no embryo formation in their life cycle.

- **Thallophyta** are divided into 2 classes:

(a) **Algae:** These are chlorophyllous plants which are **autotrophic** in their mode of nutrition. The algae may be green, blue-green, yellow, orange and red, etc., *e.g., Chlamydomonas, Ulothrix, Spirogyra, Nostoc, Ectocarpus, Batrachospermum*, etc.

(b) **Fungi:** These are non-chlorophyllous plants, which are thus **heterotrophic** in their mode of nutrition. Heterotrophic mode may be **parasitic** or **saprophytic**, *e.g., Rhizopus, Mucor, Penicillium*, Yeast, *Aspergillus, Ustilago, Alternaria*, etc.

(2) **Bryophyta:** The name bryophyta was given by Braun (1864). (Greek : *Bryon*-moss + *phyton*-plant)

These are first simplest **non-vascular land plants** which grow in moist and shady places.

- They cannot complete their life cycle on land without water, so called **'Amphibians of plant kingdom'**.

Main characters of this group are:

(a) Main plant body is **gametophytic** (n), which may be thallose (*e.g., Riccia, Marchantia*) or foliose (*e.g., Funaria, Sphagnum*).
(b) Vascular tissue (xylem and phloem) absent.
(c) Sex organs multicellular and jacketed, *i.e.*, having sterile jacket.
(d) Water is necessary for act of fertilization.
(e) Zygote ($2n$) without any resting period divides and redivides to form embryo and hence **sporophyte** or **sporogonium.**
(f) Sporophyte or sporogonium is fully or partially dependent on gametophyte or sporophyte is not independent.
(g) Having definite alternation of generations in their life cycle.

Bryophyta is further divided into two classes:

(a) **Hepaticae:** Members of this class are commonly called as **'Liverworts'**, because their plant body is liver shaped, *e.g., Riccia, Marchantia*, etc.

(b) **Musci:** Commonly called **'Mosses'** and here plant body is foliose (*i.e.*, having axis and leaves), *e.g., Funaria, Sphagnum*, etc.

(3) **Pteridophyta:** (Greek : *Pteron*-feather + *phyton*-plants), *i.e.*, having feather-like leaves or fronds.

- These are **first vascular land plants** and thus called **'Vascular Cryptogams'**.
- Pteridophytes are also called **'Snakes of plant kingdom'**.
- Main characters of pteridophytes are:

(a) The main plant is sporophytic ($2n$), differentiated into true roots, stems and leaves.
(b) Vascular tissue (xylem and phloem) is present in plant body.
(c) Sex organs are multicellular and jacketed (as in bryophyta).
(d) Embryo formation present in life.
(e) The sporophytic and gametophytic generations are morphologically distinct and **independent.**
(f) Reproduction by spores and pteridophytes may be homosporous (*i.e.*, similar type of spores) or heterosporous (*i.e.*, two different types of spores).
(g) There is regular alternation of generations in life cycle.

- **Pteridophyta** is divided into 3 classes:

(a) **Equisetineae**, *e.g., Equisetum.*
(b) **Lycopodineae**, *e.g., Lycopodium, Selaginella.*
(c) **Filicineae or Ferns**, *e.g., Dryopteris, Pteris, Adiantum*, etc.

(B) Phanerogamae (Greek : *Phaneros*-visible or evident + *gamos*-marriage) or **Flowering and seed plants** or also called **Spermatophyta** (*Sperma*-seed + *phyton*-plant).

The chief characteristics of phanerogams are:

(a) The main plant body is **sporophytic** ($2n$), whereas gametophytic generation is greatly reduced.
(b) Seed is developed after fertilization from ovule.
(c) Vascular tissue well developed and complex.
(d) Two types of spores are produced (Heterosporous). Microspores give rise to male gametophytes and megaspores give rise to female gametophytes.

- **Phanerogamae have 2 divisions:**

1. **Gymnospermae:** (Greek : *Gymnos*-naked + *sperma*-seed) or **naked seeded plants**, *i.e.*, in this group ovules or seeds are not enclosed inside ovary wall or fruit wall but borne directly on megasporophylls. Or, fruit formation is absent in gymnosperms.

- So Goebel defined gymnosperms as **'Phanerogams without ovary'**, *e.g., Cycas, Pinus, Ephedra*, etc.

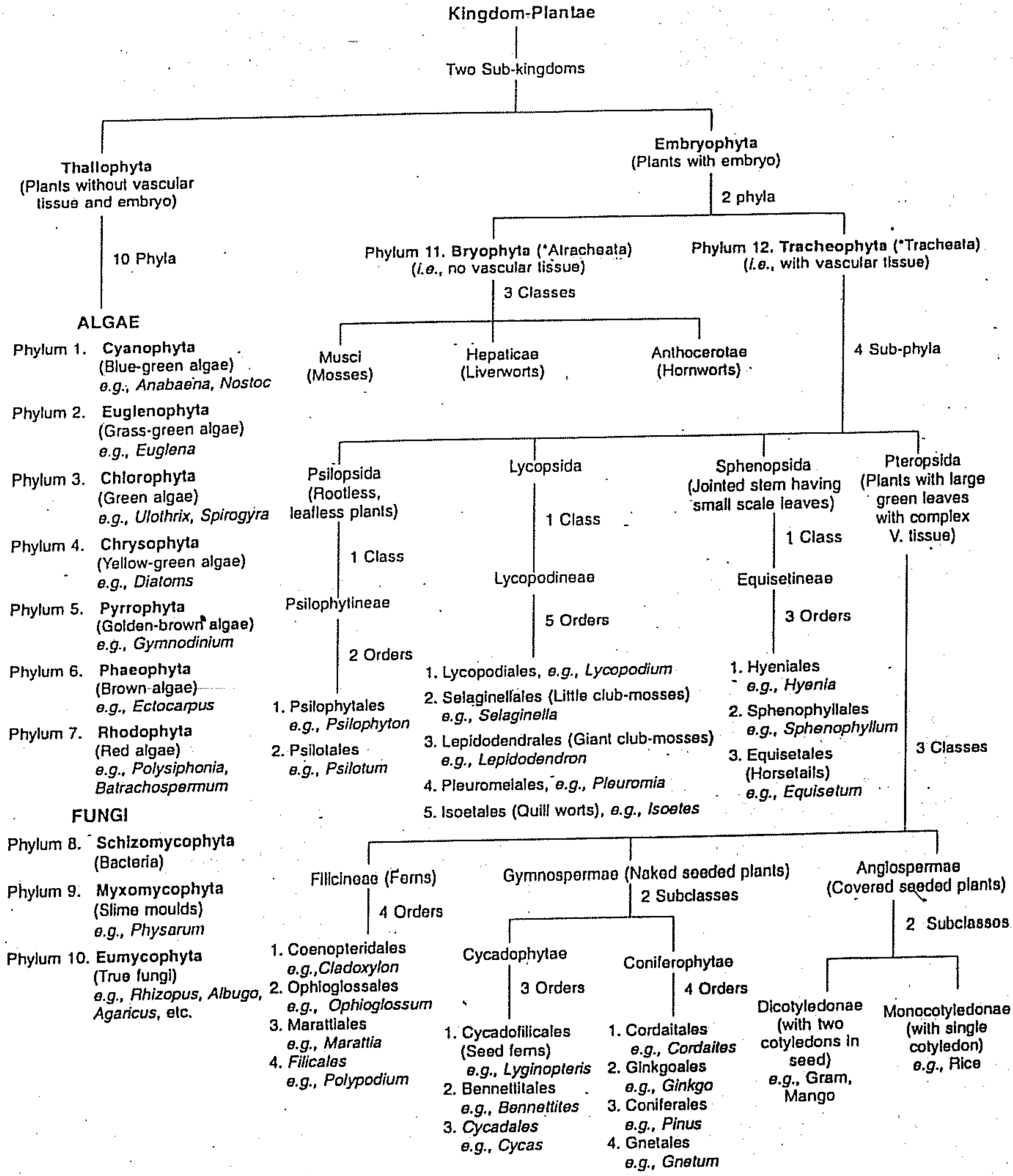
2. **Angiospermae:** (Greek : *Angeion* - encased + *sperma*-seed) or **covered seeded plants**, *i.e.*, ovules or seeds are enclosed inside ovary wall or fruit wall or seeds are present inside the fruits.

There are two classes of **angiospermae**, depending upon number of cotyledons in embryo.

(a) **Monocotyledonae:** Having single cotyledon, *e.g.*, Rice, Wheat, Maize, etc.
(b) **Dicotyledonae:** Having two cotyledons, *e.g.*, Gram, Pea, Mango, etc.

II. Tippo's classification

An American worker **Oswald Tippo** (1942) gave a system of classification of plants. This classification is mainly based on **presence or absence of vascular tissue** (xylem and phloem) and **presence or absence of embryo in life cycle.** A brief outline of this classification is given ahead:


Kingdom-Plantae
Two Sub-kingdoms
Thallophyta
(Plants without vascular tissue and embryo)
10 Phyla
ALGAE
Phylum 1. Cyanophyta
(Blue-green algae)
e.g., Anabaena, Nostoc
Phylum 2. Euglenophyta
(Grass-green algae)
e.g., Euglena
Phylum 3. Chlorophyta
(Green algae)
e.g., Ulothrix, Spirogyra
Phylum 4. Chrysophyta
(Yellow-green algae)
e.g., Diatoms
Phylum 5. Pyrrophyta
(Golden-brown algae)
e.g., Gymnodinium
Phylum 6. Phaeophyta
(Brown algae)
e.g., Ectocarpus
Phylum 7. Rhodophyta
(Red algae)
e.g., Polysiphonia, Batrachospermum
FUNGI
Phylum 8. Schizomycophyta
(Bacteria)
Phylum 9. Myxomycophyta
(Slime moulds)
e.g., Physarum
Phylum 10. Eumycophyta
(True fungi)
e.g., Rhizopus, Albugo, Agaricus, etc.
Embryophyta
(Plants with embryo)
2 phyla
Phylum 11. Bryophyta (*Atracheata)
(i.e., no vascular tissue)
3 Classes
Musci
(Mosses)
Hepaticae
(Liverworts)
Anthocerotae
(Hornworts)
Phylum 12. Tracheophyta (*Tracheata)
(i.e., with vascular tissue)
4 Sub-phyla
Psilopsida
(Rootless, leafless plants)
1 Class
Psilophytineae
2 Orders
1. Psilophytales
e.g., Psilophyton
2. Psilotales
e.g., Psilotum
Lycopsida
1 Class
Lycopodineae
5 Orders
1. Lycopodiales, e.g., Lycopodium
2. Selaginellales (Little club-mosses)
e.g., Selaginella
3. Lepidodendrales (Giant club-mosses)
e.g., Lepidodendron
4. Pleuromeiales, e.g., Pleuromia
5. Isoetales (Quill worts), e.g., Isoetes
Sphenopsida
(Jointed stem having small scale leaves)
1 Class
Equisetineae
3 Orders
1. Hyeniales
e.g., Hyenia
2. Sphenophyllales
e.g., Sphenophyllum
3. Equisetales
(Horsetails)
e.g., Equisetum
Pteropsida
(Plants with large green leaves with complex V. tissue)
3 Classes
Filicineae (Ferns)
4 Orders
1. Coenopteridales
e.g., Cladoxylon
2. Ophioglossales
e.g., Ophioglossum
3. Marattiales
e.g., Marattia
4. Filicales
e.g., Polypodium
Gymnospermae (Naked seeded plants)
2 Subclasses
Cycadophytae
3 Orders
1. Cycadofilicales
(Seed ferns)
e.g., Lyginopteris
2. Bennettitales
e.g., Bennettites
3. Cycadales
e.g., Cycas
Coniferophytae
4 Orders
1. Cordaitales
e.g., Cordaites
2. Ginkgoales
e.g., Ginkgo
3. Coniferales
e.g., Pinus
4. Gnetales
e.g., Gnetum
Angiospermae
(Covered seeded plants)
2 Subclasses
Dicotyledonae
(with two cotyledons in seed)
e.g., Gram, Mango
Monocotyledonae
(with single cotyledon)
e.g., Rice

This classification by Tippo is **phylogenetic** (based on evolutionary trends) but is not so widely accepted.

Besides these classifications of plants, some general classifications of living organisms are also being presented:

III. Whittaker's classification

R.H. Whittaker (1969) proposed a new 5 **kingdom** classification of organisms on the basis of:

(a) Complexity of body structure (*i.e.*, unicellular or multicellular).
(b) Complexity of cell structure (*i.e.*, prokaryotic or eukaryotic).
(c) Source and mode of nutrition.
(d) Life style pattern (*i.e.*, producer, consumer and decomposers).

The 5 kingdoms of organisms proposed by Whittaker are as follows:

1. Kingdom Monera,
2. Kingdom Protista,
3. Kingdom Plantae,
4. Kingdom Fungi,
5. Kingdom Animalia.

1. Kingdom Monera

This is the kingdom of **prokaryotic** organisms. The members of this kingdom can be distinguished by the following characters:

(a) A moneran cell is microscopic and does not possess well defined nucleus.
(b) DNA is **naked**, *i.e.*, not associated with histone proteins.
(c) Vacuoles are absent in cytoplasm.
(d) No cyclosis movements of cytoplasm.
(e) These organisms are lacking ER, mitochondria and Golgi bodies, but ribosomes are present.
(f) (9 + 2) pattern of flagellum structure is absent but flagellum is generally single stranded and made of **flagellin** protein.
(g) These are heterotrophic, phototrophic or chemophototrophic in their mode of nutrition.
(h) Reproduction mainly by asexual methods as fission, budding, etc., although genetic recombination (primitive sexual reproduction) occurs in a few members.

- ● Monerans are **ubiquitous** (*i.e.*, present everywhere). These are important **decomposers and mineralizers** of the biosphere.

- ● **Monera** are divided into 2 major groups:
  (i) **Archaebacteria:** Includes ancient and primitive forms of bacteria.
  (ii) **Eubacteria:** Includes true bacteria and cyanobacteria (blue-green algae).
  - ○ **Progenote** is considered to be an ancient form from which archaebacteria and eubacteria arose.

2. Kingdom Protista

This is a kingdom of **unicellular eukaryotes**. This kingdom is characterized by:

(a) Cells have definite membrane bound organelles, like ER, Golgi bodies, nucleus, etc.
(b) Both asexual and sexual methods of reproduction.
(c) Presence of cilia or flagella for locomotion.
(d) They have **autotrophic** (photosynthetic) or **heterotrophic** (parasitic or saprophytic) mode of nutrition.
(e) Mitosis and meiosis methods of cell division present.

Kingdom Protista (also called Protoctista) is divided into 3 main groups:

(i) **Photosynthetic protists** (Protistan Algae), *e.g.*, **Dinoflagellates** or class Dinophyceae (*Ceratium, Glenodinium, Gymnodinium, Gonyaulax, Noctiluca* and *Peridinium*); **Diatoms** or class Bacillariophyceae (*Navicula, Nitzchia, Melosira, Cymbella, Amphipleura, Pinnularia*) and **Euglenoids** or Euglena like flagellates (*Euglena, Eutreptia, Phacus, Peranema*).
  - ○ *Gonyaulax* causes **'red tides'** because it shows **bioluminescence** or phosphorescence and makes the sea look red.

(ii) **Consumer protists** (Slime moulds or Myxomycetes), *e.g., Physarum, Physarella.*
(iii) **Protozoan protists**, *e.g., Giardia, Trypanosoma, Leishmania, Amoeba, Entamoeba, Plasmodium* (malarial parasite), *Paramecium*, etc.

3. Kingdom Plantae

In this kingdom are included multicellular, eukaryotic, photosynthetic organisms (**kingdom of multicellular producers** or Metaphyta).

Main characters of this kingdom are:

(a) With definite cellulosic cell wall.
(b) These are basically non-motile, excepting some aquatic forms.
(c) Reproduction is primarily sexual.
(d) Presence of definite chloroplasts.
(e) Photosynthetic mode of nutrition (oxygenic photosynthesis), *e.g.*, different types of algae (green, brown, red algae), bryophytes, pteridophytes, gymnosperms and angiosperms.

4. Kingdom Fungi

This is the kingdom of eukaryotic, generally multicellular organisms having heterotrophic mode of nutrition (kingdom of **multicellular decomposers**).

Main characters of this kingdom are as follows:

(a) Absence of chlorophyll.
(b) Plant body generally filamentous **'Mycelium'** made of hyphae.
(c) Cell wall is made of chitin or fungus cellulose.
(d) Reserve food in the form of glycogen and oil globules.
(e) Reproduce both by sexual and asexual methods.
(f) Heterotrophic mode of nutrition (parasitic or saprophytic), *e.g.*, phycomycetes, ascomycetes, basidiomycetes, deuteromycetes, etc.

Fungi are also **decomposers and mineralizers** of biosphere.

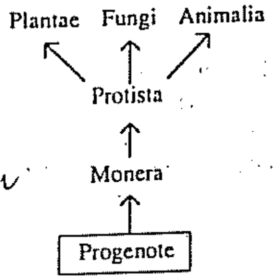
5. Kingdom Animalia

In this kingdom, all multicellular eukaryotic holozoic organisms are included (kingdom of **multicellular consumers** or Metazoa).

Main characters are:

(a) Cell wall is lacking around cell.
(b) Sexual methods of reproduction.
(c) Heterotrophic and holozoic mode of nutrition, *e.g.*, animals like sponges, molluscs, annelids, arthropods, echinoderms, amphibians, reptiles, birds, mammals, etc.

Evolution of 5 different kingdoms



mycelium

Important drawbacks of this 5 kingdom classification of Whittaker are:

(i) Unicellular green algae are not included in kingdom Protista (as it is difficult to distinguish between unicellular and multicellular forms in algae).

(ii) Viruses are not included in this classification.

IV. Six kingdom classification

Some of the modern biologists divide living organisms into six kingdoms (as they divide kingdom Monera of Whittaker into two kingdoms—Archaebacteria and Eubacteria). Thus the six kingdoms are:

1. **Kingdom Archaebacteria:** This includes the simplest and most primitive group of bacteria which can face extremes of conditions like Halophiles, Methanogens and Thermoacidophiles.
2. **Kingdom Eubacteria:** (True bacteria).
3. **Kingdom Protista or Protoctista.**
4. **Kingdom Plantae.**
5. **Kingdom Fungi.**
6. **Kingdom Animalia.**

Carl Woese (1990) divided living organisms into **3 domains** (taxonomic category above the level of kingdom) on the basis of r-RNA genes sequence:

1. **Domain-Bacteria**—It includes Eubacteria.
2. **Domain-Archae**—It includes Archaebacteria.
3. **Domain-Eukarya**—It includes Protista, Plantae, Fungi and Animalia.

- Earlier to Whittaker's 5-kingdom classification, **Linnaeus** (1758) gave the **2-kingdom classification** (Plantae and Animalia) and **Copeland** (1956) gave **4-kingdom classification** (Monera or Mychota, Protista, Plantae and Animalia).

Diversity in plants.

DIVERSITY IN PLANTS

There is a great diversity in the plant kingdom in terms of habitats, habits, form and structure, age of plants and reproduction, but there is unity among diversity as different plant groups show the fundamental characters of plants. The reason of diversity is the long term (3.5 billion years) evolutionary change on earth. Further adaptations to different ways of life are also responsible for the great diversity of life forms.

The diversity in the plant kingdom is clear by the following interesting examples of plants:

1.	Plant recorded at maximum altitude	*Ermania himalayensis* and *Ranunculus lobatus.*
2.	Smallest angiospermic plant and plant with smallest flowers	*Wolffia* (minutest duck weed) plant is 1/35 of an inch in length.
3.	Tallest trees in the world or tallest gymnosperm	*Sequoia sempervirens* (366 ft.) (Red wood tree)
4.	Tallest angiospermic tree	*Eucalyptus regnans* (375 ft.)
5.	Plant with maximum age	*Sequoiadendron giganteum* (estimated life of 6,000 yrs.)
6.	Oldest known living tree in the world	*Pinus longaeva* (in California, USA with confirmed age of 4,600 yrs.)

- Recent findings have shown that *Lagarostrobus franklinii* (ancient huon pine) growing on Mount Read (Tasmania) is the oldest known living organism, at least 10,500 years old.

7.	Smallest bryophyte	*Zoopsis argentea*
8.	Smallest pteridophyte	*Azolla*
9.	Smallest gymnosperm	*Zamia pygmea*
10.	Smallest known bacterium	*Dialister pneumonsintes*
11.	Largest known bacterium	*Epulopiscium fishelsoni* (recently discovered)
12.	Plant with smallest seeds (Dust seeds)	Orchids
13.	Plant with biggest seeds	*Lodoicea maldivica* (Double coconut or cocodemur)
14.	Plant with biggest fruit	*Lodoicea*

15.	Plant with smallest fruits	Some grasses
16.	Plant with largest leaves	*Victoria regia*
17.	Plant with longest leaves	*Raphia* (Palm)
18.	Plant with largest flower (Total root parasite)	*Rafflesia*
19.	Smallest cell	PPLO or *Mycoplasma gallisepticum*
20.	Largest plant cell	*Acetabularia* (Unicellular green alga)
21.	Smallest chromosomes	In algae (0.025 μ)
22.	Largest chromosomes	*Trillium* (30.0 μ)
23.	Plant with minimum number of chromosomes	*Haplopappus gracillis* (Compositae) ($2n = 4$)
24.	Plant with maximum number of chromosomes	*Ophioglossum* (Pteridophyte) ($2n = 1{,}262$)
25.	Fastest growing plant	*Hespiroyucca whipplei* (Liliaceae) (in 14 days grows 12 ft.)
26.	Plant with biggest egg cell	*Cycas* (Gymnosperm)
27.	Plant with biggest antherozoid	*Cycas* (Gymnosperm)
28.	Plant with biggest ovule	*Cycas* (Gymnosperm)
29.	Lightest wood	*Ochroma* (Balsa) and *Acrometogonus*
30.	Heaviest wood	*Krugiodendron* (iron wood) and *Olea lauriflora*
31.	Hardest wood	*Hardwickia*
32.	Plant bearing flowers and fruits once in life (monocarpic plant)	*Bambusa tulda* (Rothing) and *Melocanna bambusoides* (Mautak)

MULTIPLE CHOICE QUESTIONS

1. Basic unit of classification is:
(a) Family (b) Genus
[✓ (c) Species] (d) None of these

2. A plant which produces seeds but lacks flowers, will be placed in group: (CBSE 1993)
(a) Fungi (b) Bryophyta
(c) Pteridophyta (d) Gymnosperms

3. The plants which bear flowers and seeds, are:
(a) Cryptogams (b) Phanerogams
(c) Pteridophytes [✓ (d) Gymnosperms]

4. Which plant group is known as 'Vascular cryptogams'?
(a) Thallophyta (b) Bryophyta
[✓ (c) Pteridophyta] (d) Gymnosperms

5. The term 'Atracheata' is given to:
(a) Algae (b) Fungi
[✓ (c) Bryophyta] (d) Pteridophyta

6. Phanerogams include:
(a) Thallophyta
(b) Bryophyta
(c) Pteridophyta
[✓ (d) Gymnosperms and angiosperms]

7. Sex organs are multicellular and jacketed in:
(a) Algae (b) Fungi
[✓ (c) Mosses] (d) All of these

*8. A plant having thallose plant body, developing embryo and reproducing by means of spores will be placed in:
(a) Algae (b) Fungi
(c) Ferns [✓ (d) Liverworts]

9. Phanerogams without ovary are:
(a) Dicotyledons (b) Monocotyledons
(c) Pteridophytes [✓ (d) Gymnosperms]

10. The plants having vascular tissue are:
(a) Bryophyta (b) Pteridophyta
(c) Gymnosperms [✓ (d) Both (b) and (c)]

*11. The main plant body is always gametophytic (n) in:
[✓ (a) Bryophyta] (b) Pteridophyta
(c) Gymnosperms (d) Angiosperms

12. Which of the following plants is a monocot?
(a) Gram (b) Pea
[✓ (c) Rice] (d) Mango

13. The classification of Oswald Tippo is not based on:
(a) Presence or absence of vascular tissue
(b) Embryo presence or absence in life cycle
[✓ (c) Cell structure]
(d) None of the above

14. Which plant group is not included in Embryophyta of Oswald Tippo?
[✓ (a) Thallophyta] (b) Bryophyta
(c) Pteridophyta (d) Gymnosperms

15. Whittaker's classification is not based on:
(a) Complexity of body structure
(b) Complexity of cell structure
[✓ (c) Presence or absence of vascular tissue]
(d) Trophic structure

16. Monera includes:
[✓ (a) Prokaryotic organisms] (b) Unicellular eukaryotes
(c) Multicellular eukaryotes (d) All of these

17. The ancient form from which archaebacteria and eubacteria arose:
(a) Viruses (b) Cyanobacteria
[✓ (c) Progenote] (d) None of these

18. Which of the following are included in kingdom protista?
(a) Prokaryotes [✓ (b) Unicellular eukaryotes]
(c) Multicellular eukaryotes (d) None of these

19. 'Mycelium' is the plant body of kingdom:
(a) Monera (b) Protista
[✓ (c) Fungi] (d) Plantae

20. Reserve food in the form of glycogen and cell wall made of chitin are characteristic of kingdom:
(a) Protista [✓ (b) Fungi]
(c) Monera (d) All of these

21. A plant flowering and fruiting once in its life is:
(a) Monoecious [✓ (b) Monocarpic]
(c) Annual (d) Monocot

22. A plant with smallest flower in plant kingdom is: (Raj. PMT 2001)
(a) *Lemna* (b) *Rafflesia*
(c) *Wolffia* (d) *Zoopsis*

23. Plant with longest leaves is:
(a) *Victoria regia* (b) *Lodoicea*
(c) *Raphia* (d) Orchids

24. Flowering plants are included in:
[✓ (a) Phanerogams] (b) Cryptogams
(c) Bryophytes (d) Pteridophytes

25. Thallophyta includes:
[✓ (a) Algae and fungi]
(b) Fungi and bacteria
(c) Algae, fungi and lichens
(d) Algae, fungi, bacteria and lichens

26. Which of the following is having embryo but lacking vascular tissue? (Raj. PMT 1992)
[✓ (a) Bryophyta] (b) Pteridophyta
(c) Gymnosperms (d) Angiosperms

27. Most primitive vascular plants are:
(a) Cycads [✓ (b) Ferns]
(c) Red algae (d) Brown algae

28. A plant which reproduces by spores, has vascular tissue but lacks flowers should belong to: (CBSE 1992)
(a) Bryophyta [✓ (b) Pteridophyta]
(c) Algae (d) Gymnosperms

29. Which of the following plants show independent alternation of generations?
(a) Angiosperms (b) Gymnosperms
[✓ (c) Pteridophytes] (d) Bryophytes

*30. Seed habit became first established in:
(a) Mosses (b) Ferns
[✓ (c) Cycadofilicales] (d) Gnetales (gymnosperms)

F

31. Pteridophytes differ from bryophytes in having:
[✓ (a) Vascular tissues]
(b) Archegonia
(c) Alternation of generations
(d) Motile sperms

32. In which group would you place a plant which produces spores, has vascular tissue and lacks seeds: (AFMC 2002)
(a) Gymnosperms (b) Algae
[✓ (c) Pteridophytes] (d) Bryophytes

33. Seeds are characteristically found in: (Raj. PMT 1992)
(a) Bryophytes (b) Pteridophytes
(c) Gymnosperms [✓ (d) Spermatophytes]

34. Which are non-seed bearing vascular plants?
(a) Bryophytes [✓ (b) Pteridophytes]
(c) Gymnosperms (d) Angiosperms

35. Archegoniatae include:
(a) Algae, fungi and viruses
(b) Algae, lichens and bryophytes
(c) Algae, lichens and fungi
[✓ (d) Bryophytes, pteridophytes and gymnosperms]

36. Five kingdom classification of organisms was given by:
[✓ (a) Tippo] (b) Eichler
[✓ (c) Whittaker] (d) Bentham

37. Which of the kingdoms comprises of prokaryotic organisms?
(a) Protista [✓ (b) Monera]
(c) Plantae (d) Fungi

38. Non-vacuolate cells are present in:
[✓ (a) Monera] (b) Viruses
(c) Algae (d) Fungi

39. Characters of both plants and animals are present in:
(a) Mycoplasma (b) Bacteria
(c) *Paramecium* [✓ (d) *Euglena*]

40. An angiospermic plant differs from a gymnospermic plant in the absence of: (CPMT 1992)
(a) Vascular tissue [✓ (b) Ovary]
(c) Seed (d) Naked ovule

41. Which of the following lack chlorophyll?
[✓ (a) Fungi] (b) Algae
(c) Bryophyta (d) Pteridophyta

42. Gymnosperms are differentiated from angiosperms by:
[✓ (a) Naked ovule] (b) Pollen tube
(c) Stomata (d) Male gametophyte

43. Dominant terrestrial flora of present day is:
(a) Pteridophyta [✓ (b) Spermatophyta]
(c) Thallophyta (d) Bryophyta

44. Important evolutionary feature of alternation of generation from algae to flowering plant is:
(a) Gradual elaboration of gametophyte
[✓ (b) Gradual elaboration of sporophyte]
(c) Elimination of sporophyte
(d) Gradual elaboration of both gametophyte and sporophyte

45. Male and female gametophytes are greatly reduced in:
(a) Thallophyta (b) Pteridophyta
(c) Gymnosperms [✓ (d) Angiosperms]

46. In which group of plants is the gametophyte phase embedded in sporophyte?
(a) Bryophytes (b) Pteridophytes
[✓ (c) Spermatophytes] (d) Cryptogams

47. The most important character which differentiates angiosperms from gymnosperms is: (Raj. PMT 1991)
(a) Triploid endosperm
[✓ (b) Seeds enclosed in fruit]
(c) Presence of vessels in xylem
(d) Attractive petals and absence of tracheids

48. Ovules are naked in gymnosperms because:
(a) Nucellus is absent [✓ (b) Carpels are absent]
(c) Integuments are absent (d) Endosperm is absent

angiosperms from gymno-sperms

49. The division of plants into gymnosperm and angiosperm terminates with the suffix 'sperm'. It means that both produce:
(a) Motile sperms (b) Non-motile sperms
[✓ (c) Ovules and seeds] (d) Sporophylls

50. In which group would you place a plant which has vascular tissue, embryo and produces seeds?
(CBSE 1992; Raj. PMT 1992)
(a) Algae and fungi (b) Bryophytes
(c) Pteridophytes [✓ (d) Gymnosperms]

51. Egg is not present in archegonium in:
(a) Bryophytes (b) Pteridophytes
(c) Gymnosperms [✓ (d) Angiosperms]

52. Seed is defined as a fertilized ovule; one may expect to find seeds in:
(a) Gymnosperms only (b) Angiosperms only
(c) All vascular plants [✓ (d) All phanerogams]

53. Gymnosperms are plants which:
(a) Bear flowers
(b) Have no vascular tissue
[✓ (c) Produce seeds in cones but no flowers]
(d) Do not produce seeds but produce spores

54. Angiosperms differ from gymnosperms in:
(a) Type of secondary growth
(b) Geographical distribution
[✓ (c) Nature and enclosure of ovule]
(d) Dispersal of seeds

*55. Gametophytes and sporophytes are independent in:
(Raj. PMT 1992)
(a) Bryophyta [✓ (b) Pteridophytes]
(c) Gymnosperms (d) Angiosperms

56. The approximate number of known plant species is:
(a) 2,50,000 (b) 3,00,000
[✓ (c) 3,43,000] (d) 4,43,000

57. Kingdom plantae was divided into cryptogamae and phanerogamae by:
(a) Engler [✓ (b) Eichler]
(c) Tippo (d) Whittaker

58. Unicellular and non-jacketed sex organs are characteristics of:
[✓ (a) Thallophyta] (b) Bryophyta
(c) Pteridophyta (d) Spermatophyta

59. Sporophyte is partially or fully dependent in which group of plants?
(a) Thallophyta [✓ (b) Bryophyta]
(c) Pteridophyta (d) Gymnosperms

60. Which of the following are ubiquitous?
(a) Protists (b) Monerans
(c) Plants (d) Fungi

61. On the basis of evolution, which is the most primitive kingdom of organisms?
(a) Protista [✓ (b) Monera]
(c) Plantae (d) Fungi

62. Prokaryotic cells lack:
(a) Nuclear envelope and DNA
(b) DNA and mitochondria
[✓ (c) Nucleus envelope and membrane bound cell organelles]
(d) Mitochondrion and nuclear substance

63. Which of the following plant groups shows maximum adaptability?
(a) Bryophytes (b) Pteridophytes
(c) Gymnosperms [✓ (d) Angiosperms]

64. In five kingdom system of classification of Whittaker, prokaryotes belong to kingdom: (BHU 1994)
(a) Protista [✓ (b) Monera]
(c) Mycota (d) Prokaryota

65. Which is not included in the classification of Whittaker?
(a) Viruses (b) Bacteriophages
(c) Viroids and prions [✓ (d) All of these]

66. According to four kingdom classification, the unicellular, non-nucleated organisms are placed in: (BHU 1997) BZU
[✓ (a) Monera] (b) Protista
(c) Plantae (d) Animalia

67. In the five-kingdom system of classification, which single kingdom out of the following can include blue-green algae, nitrogen-fixing bacteria and methanogenic archaebacteria? (CBSE 1998, 2003) classification
[✓ (a) Monera] (b) Fungi
(c) Plantae (d) Protista

68. Total root parasite having largest flower is: (CPMT 1998)
(a) *Loranthus* (b) *Cuscuta*
[✓ (c) *Rafflesia*] (d) Lotus

69. Both plants and animals are included in which classification?
(a) Tippo's (b) Eichler's
[✓ (c) Whittaker's] (d) All of these

70. Oxygenic photosynthesis is a characteristic feature of which kingdom?
[✓ (a) Monera] (b) Fungi
[✓ (c) Plantae] (d) None of these

71. Which of the following is a precursor of Plantae, Fungi and Animalia kingdoms?
(a) Monera [✓ (b) Protista]
(c) Progenote (d) Archaebacteria

72. The practical purpose of classification of living organisms is to: (CBSE 1999)
(a) Trace the evolution of living organisms
(b) Explain the origin of living organisms
(c) Name the living organisms
[✓ (d) Facilitate the identification of unknown organisms]

*73. The Moneran devoid of cell wall is: (CPMT 2000)
(a) Actinomycetes (b) Eubacteria
[✓ (c) Mycoplasma] (d) Archaebacteria

74. Who proposed the 'Five Kingdom Classification' of organisms? (MPPMT 2000)
[✓ (a) Whittaker] (b) Bentham
(c) Linnaeus (d) Rivinus

75. The reason of diversity in living beings is: (CBSE 2001)
(a) Mutation
[✓ (b) Long term evolutionary change]
(c) Gradual change
(d) Short term evolutionary change

*76. Plant decomposers are: (CBSE 2001)
[✓ (a) Monera and fungi] (b) Fungi and plants
(c) Protista and animalia (d) Animalia and monera

77. On how many criteria living organisms have been classified into five kingdoms? (MPPMT 2001)
(a) Two (b) Three
[✓ (c) Four] (d) Five

78. The basic unit of classification of plants and animals is: (BHU 2001)
(a) Genus [✓ (b) Species]
(c) Variety (d) Sub-species

79. Decomposers are: (BHU 2001)
(a) Autotrophs [✓ (b) Heterotrophs]
(c) Autoheterotrophs (d) Organotrophs

80. Main criterion used by Whittaker in his five-kingdom classification, is: (CBSE 2002)
[✓ (a) Nuclear character] (b) Serological character
(c) Nutrition (d) None of these

81. In which of the following features gymnosperms resemble to angiosperms? (Raj. PMT 2001)
(a) Presence of vessels (b) Mode of fertilization
(c) Habit of endosperm [✓ (d) Presence of ovule] → [illegible]

82. Fungi differ from other Kingdoms in being: (DPMT 2001)
(a) Unicellular decomposers
(b) Unicellular consumers
[✓ (c) Multicellular decomposers]
(d) Multicellular consumers

83. Mark the National tree: (JIPMER 2002)
(a) *Mangifera indica* (b) *Ficus benghalensis*
(c) *Ficus religiosa* (d) *Azadirachta indica*

84. Tallest tree belongs to: (VMMC Safdarjung 2001)
(a) Monocots [✓ (b) Gymnosperms]
(c) Pteridophytes (d) None of these

85. Cryptogams are: (MGIMS Wardha 2001)
(a) Naked seeded plants [✓ (b) Non-flowering plants]
(c) Flowering plants (d) None of these

86. Flagellum with single strand and composed of flagellin is found in: (CET J&K 2002)
[✓ (a) Prokaryotes] (b) Eukaryotes
(c) Both (a) and (b) (d) None of these

87. The greatest extent of adaptation to various environments is seen in: (CMC, Vellore 2003)
(a) Gymnosperms (b) Angiosperms
(c) Bryophytes (d) Ferns

88. Angiosperms differ from gymnosperms in: (CPMT 2003)
(a) Seeds (b) Fruits
(c) Male gametophyte (d) Female gametophyte

89. If decomposers on the earth are totally extinct, the most secure effect would be that: (BHU 2003)
(a) Carnivores will not get food
(b) Biomagnification
(c) Minerals will not get recycled
(d) Nitrogen fixation will suffer

90. The replacement of two kingdom grouping by five kingdom classification was proposed in the year: (Kerala PMT 2003)
(a) 1859 (b) 1758
(c) 1862 (d) 1919
(e) 1969

91. Which of the following is not a character of a monocot? (Kerala PMT 2003)
(a) Presence of a single seed leaf
(b) Endosperm present in the mature seed
(c) Leaves with parallel veins and smooth edges
(d) Adventitious roots
(e) Floral parts as multiple of four or five

92. The plants reproducing by spores such as mosses and ferns are grouped under: (CBSE 2003)
(a) Bryophytes (b) Sporophytes
(c) Thallophytes (d) Cryptogams

93. Which of the following pairs of plants is not seed producer? (CBSE 2003)
(a) *Funaria* and *Ficus*
(b) *Funaria* and Fern
(c) *Punica* and *Pinus*
(d) *Ficus* and *Chlamydomonas*

*94. Which of the following pairs correctly represents the grouping spermatophyta according to one of the schemes of classifying plants? (CBSE 2003)
(a) *Pinus, Cycas* (b) *Ginkgo, Pisum*
(c) *Acacia, Casuarina* (d) *Rhizopus, Triticum*

95. Which of the following is true for angiosperms? (CMC, Vellore 2003)
(a) They have naked seeds (b) They are not cryptogams
(c) They have tracheids (d) They lack companion cells

96. Cyanobacteria is: (CPMT 2003)
(a) Algae having blue-green pigment
(b) Algae having red pigment
(c) Algae having brown pigment
(d) Algae having yellow-brown pigment

ANSWERS

1—c	2—d	3—b	4—c	5—c	6—d	7—c	8—d	9—d	10—d	11—a	12—c
13—c	14—a	15—c	16—a	17—c	18—b	19—c	20—b	21—b	22—c	23—c	24—a
25—a	26—a	27—b	28—b	29—c	30—c	31—a	32—c	33—d	34—b	35—d	36—c
37—b	38—a	39—d	40—b	41—a	42—a	43—b	44—b	45—d	46—c	47—b	48—b
49—c	50—d	51—d	52—d	53—c	54—c	55—b	56—c	57—b	58—a	59—b	60—b
61—b	62—c	63—d	64—b	65—d	66—a	67—a	68—c	69—c	70—c	71—b	72—d
73—c	74—a	75—b	76—a	77—c	78—b	79—b	80—a	81—d	82—c	83—b	84—b
85—b	86—a	87—b	88—b	89—c	90—e	91—e	92—d	93—b	94—b	95—b	96—a

EXPLANATION OF SELECTED QUESTIONS (*)

8. In bryophytes, embryo formation occurs in gametophytic thallose body and inside the capsule of sporophyte, spores of the same type are produced.

11. In all bryophytes, the main plant body is always gametophytic (n), which may be thallose or foliose.

30. Cycadofilicales or Pteridospermales (seed ferns) is the simplest order of gymnosperms, where seed habit was first established.

55. In ferns (pteridophytes), prothallus is independent (autotrophic) haploid plant of gametophytic generation concerned with sexual reproduction, produced by germination of spore.

73. Mycoplasma or PPLO differ from bacteria in lacking cell wall.

76. Most of the monerans and fungi are saprophytic and hence these are decomposers and mineralizers of biosphere.

94. Spermatophyta includes gymnosperms and angiosperms.

TEST PAPER—UNIT-1

1. Phytology is:
(a) Study of all living organisms
[✓ (b) Study of plants]
(c) Study of animals
(d) None of the above

2. '*Historia Plantarum*' was written by:
(a) Aristotle [✓ (b) Theophrastus]
(c) Linnaeus (d) Dioscorides

3. Father of Indian Botany is:
(a) Theophrastus (b) William Roxburgh
(c) Father Santapau (d) P. Maheshwari

historia plantarum

4. Physical basis of life is:
(a) Cell [✓ (b) Protoplasm]
(c) Food (d) None of these

5. Localized growth is a characteristic feature of:
(a) Plants [✓ (b) Animals]
(c) Plants and animals (d) None of these

6. Autotrophic mode of nutrition occurs in:
(a) Animals [✓ (b) Plants]
(c) Both (a) and (b) (d) None of these

7. Famous Indian morphologist is:
(a) P. Maheshwari (b) V. Puri
(c) R. Mishra (d) K.K. Nanda

8. Who is called 'Father of Modern Genetics'?
(a) Mendel [✓ (b) T.H. Morgan]
(c) Punett (d) Hugo de Vries

9. Study of heredity and variations is done under which branch of botany?
(a) Ecology [✓ (b) Genetics]
(c) Cytology (d) Taxonomy

10. Prof. Birbal Sahni is associated with which branch of botany?
(a) Taxonomy (b) Ecology
(c) Phytogeography (d) Palaeobotany

11. Who is called 'Father of Mycology'?
(a) E.J. Butler (b) F.E. Fritsch
[✓ (c) Micheli] (d) M.O.P. Iyengar

12. Study of plants of tribal use is done under:
(a) Agrostology (b) Edaphology
[✓ (c) Ethanobotany] (d) Dendrology

theophrastus

13. Applying principles of mathematics and statistics to biological data constitutes the branch:
(a) Biophysics [✓ (b) Biometrics]
(c) Exobiology (d) Biochemistry

14. Spermology is the study of:
[✓ (a) Seeds] (b) Sperms or antherozoids
(c) Pollens or microspores (d) None of these

15. Person responsible for green revolution in India is:
(a) N. Borlaug (b) M.S. Swaminathan
(c) K.C. Mehta (d) R. Mishra

16. Who studied annual recurrence of wheat-rust in India?
(a) E.J. Butler (b) Swaminathan
(c) K.C. Mehta (d) P.K.K. Nair

17. N. Borlaug, who received the Nobel Peace Prize of 1970 is a/an:
(a) American microbiologist (b) Indian wheat breeder
(c) Mexican rice breeder (d) Mexican wheat breeder

18. Indian Botanical Garden is located at:
(a) Lucknow (b) Kolkata
(c) Delhi (d) Hyderabad

19. National Botanical Research Institute (NBRI) was earlier known as:
(a) Indian Botanical Garden
(b) National Botanical Garden
(c) Royal Botanical Garden
(d) IARI

20. Which of the following is popularly known as 'Pusa Institute'?
(a) IARI (b) FRI
(c) CDRI (d) NBRI

21. 1 Å (Angstrom) is equal to:
(a) $10^{-4}\,\mu$ (b) 10^{-7} mm
(c) 10^{-10} m [✓ (d) All of these]

22. 1 μ (micron) is equal to:
[✓ (a) 10^{-3} mm] (b) 10^{-4} mm
(c) 10^{-6} mm (d) None of these

23. The classification of organisms comes under:
(a) Ecology [✓ (b) Taxonomy]
(c) Cytology (d) Genetics

24. The name bryophyta was given by:
[✓ (a) Braun] (b) Eichler
(c) Tippo (d) Whittaker

25. The members of class hepaticae of bryophytes are commonly known as:
[✓ (a) Liverworts]
(b) Hornworts
(c) Amphibians of plant kingdom
(d) Mosses

26. A system of classification of plants on the basis of presence or absence of vascular tissue and embryo was given by:
(a) Eichler [✓ (b) Oswald Tippo]
(c) Whittaker (d) Goebel

27. The classification of plants given by Tippo is:
(a) Artificial (b) Natural
[✓ (c) Phylogenetic] (d) None of these

28. A microscopic cell without well defined nucleus and absence of vacuoles in cytoplasm is characteristic of kingdom:
[✓ (a) Monera] (b) Protista
(c) Fungi (d) Plantae

29. The plant recorded at maximum altitude is:
(a) *Sequoia gigantea* (b) *Ermania himalayensis*
(c) *Wolffia* (d) *Zoopsis argentea*

30. Plant having largest leaves is:
(a) *Victoria regia* (b) *Raphia*
(c) *Lodoicea* (d) *Zamia*

31. Fastest growing plant is:
(a) *Victoria regia* (b) *Hespiroyucca whipple*
(c) *Ophioglossum* (d) *Trillium*

32. Cyanobacteria is the new name given to:
[✓ (a) Myxophyceae] (b) Myxomycetes
(c) Schizomycetes (d) Archaebacteria

33. A famous palaeobotanist of India is:
(a) D.D. Pant (b) Birbal Sahni
(c) Both (a) and (b) (d) S.R. Kashyap

34. Complete kingdom is represented by:
(a) Algae [✓ (b) Fungi]
(c) Bryophyta (d) Angiosperms

35. A plant with delicate stem and having height less than one metre will be included in:
[✓ (a) Herbs] (b) Shrubs
(c) Trees (d) None of these

36. Unicellular and non-jacketed sex organs are present in:
(a) Algae (b) Fungi
[✓ (c) Both (a) and (b)] (d) Bryophytes

37. A plant producing flowers and fruits once in its life is called:
(a) Holocarpic [✓ (b) Monocarpic]
(c) Perennial (d) Annual

38. An organism having rigid cell wall and embryo in its life cycle will be placed in kingdom:
(a) Monera (b) Protista
[✓ (c) Plantae] (d) Fungi

39. The simplest non-vascular land plants are:
(a) Algae (b) Fungi
[✓ (c) Bryophyta] (d) Pteridophyta

40. A plant is having gametophytic, thallose main plant body and multicellular, jacketed sex organs will be placed in:
(a) Thallophyta [✓ (b) Bryophyta]
(c) Pteridophyta (d) Gymnospermae

ANSWERS

1—b	2—b	3—b	4—b	5—a	6—b	7—b	8—b	9—b	10—d	11—c	12—c
13—b	14—a	15—b	16—c	17—d	18—b	19—b	20—a	21—d	22—a	23—b	24—a
25—a	26—b	27—c	28—a	29—b	30—a	31—b	32—a	33—c	34—b	35—a	36—c
37—b	38—c	39—c	40—b								

UNIT-1

ASSERTION AND REASON TYPE QUESTIONS

In the questions given below, two statements—an Assertion (A) and a Reason (R) are given. Give the appropriate response as:

- (a) *If both A and R are true and R is the correct explanation of A.*
- (b) *If both A and R are true but R is not the correct explanation of A.*
- (c) *If A is true but R is false.*
- (d) *If both A and R are false.*
- (e) *If A is false but R is true.*

1. A: Life is not possible without protoplasm. a
   R: All vital activities occur in protoplasm.
2. A: Biology is the science of exceptions.
   R: There are very few universal laws in biology and living organisms show numerous variations.
3. A: Theophrastus is called father of botany.
   R: Theophrastus was a Greek naturalist.
4. A: Respiration is primarily an energy yielding process.
   R: Oxidation of food materials occurs to release energy.
5. A: Growth is the final end product of successful metabolism.
   R: Catabolic processes are more than anabolic processes in growth.
6. A: Green plants convert radiant energy of the sun into chemical form of energy.
   R: In photosynthesis, carbohydrates are broken down into CO_2 and H_2O.
7. A: The study of origin of living beings and their gradual changes is called Phytogeography.
   R: Diversity of living beings is due to short term evolution.
8. A: Growth continues up to the end of life in plants.
   R: In plants, growth is restricted to special regions.
9. A: In gymnosperms, seeds are not inside the fruits.
   R: Gymnosperms are phanerogams without ovary.
10. A: In kingdom—Monera, DNA is naked.
    R: DNA is not associated with histone proteins in monerans.
11. A: 9 + 2 pattern of flagellum structure is absent in kingdom—Monera.
    R: Flagellum is made of flagellin protein in bacteria.
12. A: A protist *Gonyaulax* causes 'red tides'.
    R: *Gonyaulax* shows the property of bioluminescence.
13. A: Fungi are decomposers and mineralizers of biosphere.
    R: A large number of fungi are saprophytic in their mode of nutrition.
14. A: Plant body in kingdom—Fungi is generally mycelium.
    R: Reserve food material is in the form of glycogen and oil globules in fungi.
15. A: In kingdom—Plantae, photosynthesis is oxygenic. b
    R: Water is utilized in the process of photosynthesis.
16. A: There is great diversity in plant kingdom.
    R: Adaptations to different ways of life are responsible for diversity of life-forms.
17. A: It is not possible to study a huge variety of plant species without their classification.
    R: Tracing of origin and evolution of organisms is not the purpose of classification.
18. A: In thallophyta, sex organs are multicellular and jacketed.
    R: Embryo formation occurs in the life cycle of thallophytes.
19. ~~A: Classification of organisms comes under Taxonomy.~~
    R: A.P. de Candolle gave the term Taxonomy.
20. A: Archaebacteria include the simplest and most primitive group of bacteria.
    R: Archaebacteria can face extremes of conditions.
21. A: Plants lack excretory organs. (AIIMS 1997)
    R: Plants absorb only essential nutrients and lead a passive life.
22. A: Living organisms possess specific individuality with the definite shape and size. (AIIMS 1999)
    R: Both living and non-living entities resemble each other at the lower level of organization.
23. A: Study of biology requires basic knowledge of chemistry and physics. (AIIMS 2002)
    R: Living organisms are made of atoms and molecules which follow chemical and physical laws.
24. A: Systematics is the branch of biology that deals with classification of living organisms. (AIIMS 2002)
    R: The aim of classification is to group the organisms in an orderly manner.

ANSWERS

1. (a) 2. (a) 3. (b) 4. (a) 5. (c) 6. (c) 7. (d) 8. (b) 9. (a) 10. (a)
11. (b) 12. (a) 13. (a) 14. (b) 15. (a) 16. (a) 17. (c) 18. (d) 19. (b) 20. (b)
21. (a) 22. (b) 23. (a) 24. (b)

UNIT-2

is taken
due to
breaking
of H_2O
rather than
CO_2.

Oh. GOD.
please forgive me
and accept my
right prayers
about myself and
my mother.
Thanks.

- Tools and Techniques Used in Cytology
- Structural and Functional Organization of Cell
- Energy Flow in the Life of a Cell
- Cell Division
- Test Paper—Unit-2
- Assertion-Reason Type Questions—Unit-2

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Study of cells

3

Tools and Techniques Used in Cytology

- 1 ☐ Microscopes: Compound or light, phase contrast, dark-field, interference, fluorescence, polarizing, ultraviolet, electron
- 2 ☐ Sectioning
- 3 ☐ Staining
- 4 ☐ Cytochemistry
- 5 ☐ Microspectrophotometry
- 6 ☐ Cell fractionation
- 7 ☐ Autoradiography
- 8 ☐ Chromatography
- 9 ☐ X-ray crystallography

For the advancement of researches in science and to increase our knowledge about minute things, various tools and techniques have been used by the workers. Some of the important ones are:

MICROSCOPES

First of all Leeuwenhoek (1683) used hand lenses to study a thin slice of bottle cork. Then Robert Hooke in the 18th century used a compound microscope. Later on various improvements have been done in microscopy. The different types of microscopes used nowadays are:

(i) Compound or Light microscope

It was invented by Z. Janssen. It is the simplest, widely used microscope having three parts, *i.e.*, condenser, which collects the light rays and precisely focuses them on the object; **objective lens**, which magnifies the image by three objective lenses, *i.e.*, **low power, high power** and **oil immersion lenses** and **ocular or eyepiece lens**, which further magnifies the image.

4 Magnifying power

- The magnifying power is represented by the symbol 'X'. The total magnification of a microscope is obtained by multiplying the objective magnification and ocular lens magnification, *e.g.*, if the magnifying power of an ocular lens is 10X and of the objective is 40X, then the total magnifying power of a microscope is $10 \times 40 = 400X$.
- In a compound microscope an object can be magnified upto 1000 times and the magnification is independent of intensity of light, size of microscope and numerical aperture.

Resolving power

4 Resolving power

It is the ability of a system to distinguish two close points as two separate points.

- Resolving power of a microscope depends upon the **numerical aperture of the objective lens system** and its **wavelength.** In a compound microscope the visible light of wavelength from **3900 Å to 7600 Å** is the source of illumination for the object. Depending upon the type of **visible light** used, the **resolving power of a light microscope** ranges from **0.2 μm to 0.4 μm** (in blue light).
- Resolving power of human eye is **100 μ.**

(ii) Phase contrast microscope

It was invented by **Zermicke** in **1935** and was awarded the Nobel Prize in 1953 for this work. In phase contrast microscope the living cells and tissues can be studied without fixing and staining them, *e.g.*, chromosomes in the living cell.

- The visible light is the source of illumination as in the ligh microscope. The beam of light splits and passes through the various cell components, majority of which are transparen having different refractive indices. Because of this difference, phase variation results. These phase variations ar visible as light or contrast through the optical system o phase contrast microscope.
- Like the compound or light microscope, the only drawbac of phase contrast microscope is its low magnifying powe so the sub-cellular organelles smaller than 0.2 μ, lik ribosomes, lysosomes, endoplasmic reticulum, cannot b visualised.

(iii) Dark-field microscope

The objects which do not refract light are seen under dark fiel microscope. A special condenser having an opaque disc is use from which oblique light is provided. All objects of a cell havin different refractive indices from the surrounding medium can b seen as brightly illuminated bodies. This microscope was developed by **Zsigmondy** (1905).

(iv) Interference microscope

This microscope is based on the principles similar to phase contrast microscope. It was invented by **Merten** *et al.* In this microscope the components of cell, according to their densities, show contrast of variable intensities.

In interference microscope daylight is the source of illumination. Interference microscope is used for quantitative studies of cell components and is helpful in finding out various constituents of cell, *i.e.*, **proteins, nucleic acids, lipids**, etc. The thickness of an object of the cell can also be measured by this microscope.

(v) Fluorescence microscope

It is observed that when ultraviolet light is irradiated on certain chemical substances, they absorb it and emit visible light. These chemical substances are called fluoro-chromes. The fluorescent substances, *e.g.*, quinine sulphate, rhodamine and auramine are used to stain the cellular objects and these objects are easily visible as fluorescent areas when illuminated with ultraviolet light. It was developed by Coons (1945).

(vi) Polarizing microscope

In this microscope the plane polarised light is used as a source of illumination. Unlike the ordinary light, plane polarised light vibrates only in one direction and the cellular objects are easily visible as they appear bright against the dark ground. Polarizing microscope is helpful in studying the spindle fibres in the cells.

(vii) Ultraviolet microscope

In this microscope the source of illumination is ultraviolet radiations having shorter wavelengths (1500 Å–3500 Å) as compared to ordinary visible light. In this microscope, the lenses are made of fluoride, lithium fluoride or quartz instead of glass.

- Ultraviolet microscope is helpful in quantitative determination of all those cell components which absorb ultraviolet rays, *e.g.*, those places where high concentration of nucleic acids is found, appear as darker regions than the remaining cell components.

(viii) Electron microscope

This was developed by **M. Knoll and E. Ruska** (1932) in Germany. It is the best device to determine the **ultrastructure of a cell organelle.**

- Electron microscope can magnify the objects upto 2,00,000 times (now possible upto 2,50,000–4,00,000) and direct study of objects is possible on this microscope. Presence of ribosomes is revealed with the help of electron microscope.
- The resolving power of the electron microscope is 10 Å which is **100 times** more than the **light microscope**. This high resolution power is because of the very low wavelength (0.005 mμ) of the electron beam used as light source. It is produced when a metal filament is heated in a vacuum tube at high temperature, *i.e.*, 50,000 volts.
- Electron microscope is made up of **electromagnetic** lenses.

The beam of electrons is focussed on the object with the help of a condenser lens and a magnified image of the object is formed by the objective lens. This magnified image is further magnified by a projector lens and final image is produced on fluorescent screen. If this image is to be recorded permanently then photographic film should be used instead of fluorescent screen.

Electron microscopes are of two types:

(a) Transmission Electron Microscope (TEM)

Study of living cells cannot be done through this microscope because of high voltage, which is required to operate it, kills the living materials.

Fine structure of the objects can be observed by this microscope. Very thin sections of the object are prepared and stained with heavy metal, *i.e.*, gold or palladium. Now after staining these are placed in vacuum chamber of microscope and an electron beam of tremendous voltage, *i.e.*, 1,00,000 volt is focussed on the section. Now the image is formed which can be magnified over 20 million times with resolution. The resolution power of TEM is **2 nm**.

(b) Scanning Electron Microscope (SEM)

In this microscope the beam of electrons is reflected back from the object and an image is formed having three dimensional appearance. The maximum magnification which can be done with the help of this microscope is nearly about 20,000 times while the resolution of SEM is **5–20 nm**. Cell surfaces and objects of larger size can be studied with the help of this microscope.

SECTIONING

For the microscopic studies of biological materials it is essential to cut thin sections of these materials. It can be done either by hand sectioning with the help of razor or by section cutting machines called microtomes. Microtome was invented by **W. His**. In electron microscope thin sections of 20–100 nm are required, for this ultramicrotome and glass knife of diamond are used.

STAINING

Most of the cell components are transparent; so to make these components visible, different dyes are used to stain them. The cellular components take up these dyes according to their chemical nature. Some of the dyes used to stain various cell components are as follows:

Stain	Used for staining	Final colour
1. Acetocarmine	Chromosomes	Pink
2. Acid fuchsine	Cortex, cellular walls, mitochondria	Magenta
3. Aniline blue	Fungal hyphae	Blue
4. Basic fuchsine	Nucleus	Magenta red
5. Crystal violet	Bacteria	Violet
6. Eosin	Cytoplasm	Pink

Stain	Used for staining	Final colour
7. Feulgen's stain	DNA	Purple or red
8. Hemotoxyline	Nuclei, cell wall and cellulose	Violet
9. Iodine solution	Starch	Blue
10. Janus green	Fungi and mitochondria	Green
11. Methylene blue	Yeast and Golgi complex	Blue
12. Phloroglucinol + HCl	Lignin	Red
13. Ruthenium red	Pectin	Red
14. Safranin	Nuclei, lignified tissues	Red
15. Sudan-III or IV	Suberin, cutin, oil	Red
16. Sudan black	Fatty substance	Black
17. Toludine blue	RNA	Blue

Out of these stains, some stains can be used for staining living materials as they are non-toxic; such stains are called **vital stains**, *e.g.*, methylene blue, neutral red, janus green, malachite green, etc.

pigm only

[illegible]

CYTOCHEMISTRY

This is a technique in which specific constituents within the cells are located by producing colour contrasts at the specific sites, with the help of **specific dyes**, *e.g.*, **Schiff's reagent** is used to localise the DNA within a cell. Similarly, **Azure B** is used for RNA.

MICROSPECTROPHOTOMETRY

It is a device used for quantitative estimation. This technique is based on the fact that the amount of dye taken up is directly proportional to the amount of stained component. With the help of this technique, it was established that the DNA content of the cell nuclei is characteristic of the given species.

It is observed that different substances absorb maximum light at a characteristic wavelength and by measuring the amount of light absorbed the amount of substance can be estimated.

CELL FRACTIONATION

For the biochemical analysis of various cell components, *i.e.*, mitochondria, nucleus, Golgi complex, ribosomes, etc., it is essential to separate them and this can be done with the help of this technique. This process is completed in two steps, *i.e.*, homogenisation and centrifugation.

(I) Homogenisation

In this process the cell wall is ruptured to release sub-cellular components. This process is carried out in a sucrose solution (0.25 M) or cesium chloride solution at a low temperature (0–4°C) in order to prevent breakdown of cell components. This mixture, having homogenized components of cell is called homogenate.

(II) Centrifugation

The homogenate is subjected to different centrifugal forces in a centrifuge. Depending upon the shape, size and density different sub-cellular components are separated.

chromatography

Classical cell fractionation technique may be summarized as follows:

Homogenate in 0.25 sucrose solution or cesium chloride solution

1st centrifugation ↓ 700 × g for 10 min.

Supernatant-I + Sediment-I ■ Nuclei

2nd centrifugation ↓ 5000 × g for 10 min.

Supernatant-II + Sediment-II ■ Mitochondria

↓

Redispensed

3rd centrifugation ↓ 24,000 × g for 10 min.

Supernatant-IIa + Sediment-IIa ■ Mitochondria and Lysosomes

4th centrifugation ↓ 54,000 × g for 10 min.

Supernatant-III + Sediment-III ■ Microsome, *i.e.*, broken ER, ribosomes, Golgi bodies, etc.

5th centrifugation ↓ 1,00,000 × g for 10 hrs.

Supernatant-IV + Sediment-IV ■ Soluble enzymes and N. acids

■ Ribosomes

malachite
malachite green

AUTORADIOGRAPHY

This technique helps to study the synthesis of molecules and t trace the metabolic events occurring inside the cell. Autoradiography is carried out with the help of radioactive isotopes calle tracers; these are incorporated into the cell and their path i followed with the help of radiations. Some of the commonly use radioactive isotopes are **carbon (C^{14})**, **tritium (H^3)**, **iodine (I^{131}** and **phosphorus (P^{32})**. Autoradiography is also helpful in studyin the replication of chromosomes. Tritiated (H^3) and carbon-labelle (C^{14}) compounds of thymidine, uridine and amino acids are use in the study of the synthesis of DNA, RNA and proteins respectively.

respectively.

CHROMATOGRAPHY

(Greek words, *Chroma*, colour; *Graphs*, writing)

Michael Tswett (1906), a Russian botanist, discovered th technique of chromatography. With the help of this techniqu molecules of different substances are separated present in solution. This separation depends upon the differential moveme of each component through a stationary medium under the i fluence of a moving solvent, *e.g.*, the individual pigments of gree leaf carotene, chlorophyll and xanthophyll appear as coloure bands when these pigments are dissolved in petroleum-ether and are allowed to separate in columns of powdered calcium carbonate. Depending upon the stationary medium chromatography is of the following types:

(i) Paper chromatography
(ii) Thin layer chromatography (TLC)
(iii) Column chromatography
(iv) Partition chromatography
(v) Ion exchange chromatography.

X-RAY CRYSTALLOGRAPHY

In this technique, X-rays pass through a crystal of a substance and form a diffraction pattern. With the help of this technique, the arrangement of atoms in the molecular structure of enzymes, proteins, DNA, etc., can be studied.

- **Wilkins, Watson** and **Crick** used this technique to determine the molecular configuration of double helix of DNA.

MULTIPLE CHOICE QUESTIONS

1. A compound or light microscope was invented by:
(a) Leeuwenhoek (b) Zernike
(c) Z. Janssen (d) Knoll and Ruska

2. The most important property of a microscope is: **(Raj. PMT 1991)**
(a) Its magnification
(b) Its resolution
(c) Its ability to show in three dimensions
(d) Its ability to use larger wavelengths

3. Light microscope has a resolving power of:
(a) 0.2 micrometers (b) 0.3 micrometers
(c) 0.1 micrometers (d) 0.4 micrometers

*4. How many lenses are present in a compound microscope? **(AFMC 2000)**
(a) One (b) Two
(c) Three (d) Four

5. Ability to distinguish two closely packed objects is: **(BHU 1996)**
(a) Resolving power (b) Video power
(c) Distinguishing power (d) Magnifying power

6. To determine the ultrastructure of a cell organelle, the most likely method to be used would be: **(CPMT 1990; BHU 1991)**
(a) Electron microscopy
(b) Microdissection
(c) Autoradiography
(d) Phase contrast microscopy

7. The magnifying power of a light microscope is about:
(a) 2,000 times (b) 1,500 times
(c) 1,000 times (d) 500 times

8. For the study of cell, the technique used other than microscopy is: **(AFMC 1998)**
(a) Plasmolysis (b) Obliteration
(c) Autoradiography (d) All of these

9. The resolution achieved with the help of electron microscope is: **(CET Chandigarh 1997)**
(a) 10 Å (b) 15 Å
(c) 20 Å (d) 5 Å

10. One micron is equal to:
(a) 1/10 of a mm (b) 1/100 of a mm
(c) 1/1000 of a mm (d) 1/10,000 of a mm

11. The maximum magnification achieved with an electron microscope is:
(a) 2,00,000 times (b) 2,000 times
(c) 200 times (d) 20,000 times

12. Electron microscope is made up of:
(a) Objective and ocular lenses
(b) Polarizer and analyzer filters
(c) Electromagnetic lenses
(d) Fluorochromes

13. The quantitative estimation of substances in a cell can be done with the help of:
(a) Autoradiography (b) X-ray crystallography
(c) Chromatography (d) Microspectrophotometry

*14. In an electron microscope higher magnification is due to the use of: **(CBSE 1990)**
(a) Higher wavelengths of Light
(b) High velocity electrons
(c) Achromatic lenses
(d) Magnetic system

15. Phase contrast microscope was invented by:
(a) Zernike (b) Leeuwenhoek
(c) Janssen (d) Knoll and Ruska

16. In interference microscope the source of light is:
(a) Beam of electrons (b) Daylight
(c) Ultraviolet rays (d) None of these

17. In Feulgen test, the dye used is:
(a) Janus green (b) Neutral red
(c) Basic fuchsin (d) Sudan black

18. Microscope which uses high wavelength ultraviolet rays is:
(a) UV microscope
(b) Phase contrast microscope
(c) Fluorescence microscope
(d) All of the above

19. Living materials can be studied by:
(a) Dark field microscope
(b) Interference microscope
(c) Phase contrast microscope
(d) All of the above

20. Which is a pre-requisite for electron microscope?
(a) Vacuum (b) Living material
(c) Source of light (d) Reflector

21. A living cell cannot be studied under: **(BHU 1993)**
(a) Light microscope (b) Compound microscope
(c) Electron microscope (d) All of these

22. The unit of measurement of light microscope is:
(a) Millimetre (b) Svedberg unit
(c) Angstrom (d) Micron

23. One angstrom is equal to: **(CBSE 1992)**
(a) 0.01 µm (b) 0.001 µm
(c) 0.0001 µm (d 0.00001 µm

24. The minimum cell size that can be seen by light microscope is: **(BHU 1993)**
(a) 1 µ (b) 0.5 µ
(c) 0.25 µ (d) 0.1 µ

25. The transmission electron microscope (TEM) has a resolution of: **(MPPMT 1993)**
(a) 2,000 nanometres (b) 200 nanometres
(c) 2 nanometres (d) 0.2 nanometre

26. 1 mµ (millimicron) is equal to: **(CPMT 1992)**
(a) 10^{-5} mm (b) 10^{-6} mm
(c) 10^{-7} mm (d) 10^{-8} mm

27. Cell organelles can be separated by:
(a) Autoradiography
(b) Thin section microtomy
(c) Differential centrifugation
(d) X-ray diffraction

28. A particular cell from a mixture can be separated by:
(a) Flow cytometry (b) Chromatography
(c) Microscopy (d) Fractionation

29. Which technique other than electron microscopy is used in the fine structure of a cell?
(a) Plasmolysis (b) Chromatography
(c) Crystallography (d) Oblceraturs

30. Electron microscope was invented by: (Raj. PMT 2001)
(a) Knoll and Ruska (b) Fleming and Brown
(c) Schleiden and Schwann (d) None of these

31. If the cells are broken up and sedimented, the new structure formed in one of the fractions is:
(a) Centrosome (b) Lysosome
(c) Microsome (d) Ribosome

32. Which of the following is related to Genetic Engineering?
(a) Plastids (b) Plasmids
(c) Mutations (d) Hybrid vigour

33. Feulgen reaction is a technique developed by Feulgen and Rossenbeck to study or to stain:
(a) Protein (b) Lipids
(c) DNA (d) RNA

34. Electron microscope has revealed the presence of:
(a) Leucoplasts (b) Chloroplasts
(c) Chromosomes (d) Ribosomes

35. The higher resolution of an electron microscope is due to: (CBSE 1990)
(a) Low wavelength of ultraviolet radiation as a light source
(b) High numerical aperture of a series of glass lenses
(c) Powerful electromagnetic lenses
(d) Very low wavelength (0.005 mm) of electron beam used as light source

36. The stains used in fluorescent microscopy are:
(a) Rhodamine (b) Safranin
(c) Orcein (d) None of these

37. Resolving power of an electron microscope is:
(a) About 500 times of light microscope
(b) About 50 times of light microscope
(c) More than 1000 times
(d) More than 100 times of light microscope

38. Metabolic processes can be studied by means of:
(a) Light/Compound microscope
(b) Autoradiography
(c) Phase contrast microscope
(d) Electron microscope

39. Detection and isolation of organic compound present in traces in a living cell can be done by:
(a) Chromatography (b) Microscopy
(c) Tracer technique (d) Centrifugation

40. For differential centrifugation, homogenate of tissue is made in:
(a) NaCl solution
(b) Cesium chloride solution
(c) Cesium hydroxide solution
(d) Water

41. In centrifugation which one settles as sediment first?
(a) Ribosomes (b) Mitochondria
(c) Nuclei (d) None of these

42. After homogenization and sedimentation by centrifugation a new structure is formed called:
(a) Centrosome (b) Lysosome
(c) Microsome (d) Ribosome

43. A vital dye for staining mitochondria is:
(a) Methylene blue (b) Janus green
(c) Neutral red (d) Acetocarmine

44. Cellulosic cell wall can be specifically stained by:
(a) Methylene blue (b) Sudan-IV
(c) Schultz reagent (d) Janus green

45. Which of the following isotopes is non-radioactive?
(a) C^{14} (b) H^{3}
(c) P^{31} (d) O^{18}

46. Which of the following microscopes has the highest resolving power?
(a) UV microscope (b) Polarising microscope
(c) Electron microscope (d) Fluorescence microscope

47. Iodine solution is used to test the presence of:
(a) Carbohydrates (b) Proteins
(c) Fats (d) Starch

48. Vital stains are used in the study of:
(a) Fixed tissues (b) Frozen tissues
(c) Living cells (d) None of these

49. Dyes which glow the cellular structures under UV radiations are:
(a) Fluorescent (b) Auto-fluorescent
(c) Fluorochromes (d) None of these

50. A fluorescence microscope is used:
(a) To localise cell structure
(b) To study cells and their components in a living state using phase difference in light rays
(c) For increasing resolving power
(d) For obtaining X-rays diffraction pattern of DNA

51. One of the important techniques used to study the synthesis of molecules and to trace the metabolic pathways in cells is:
(a) Calorimetery (b) Chromatography
(c) Autoradiography (d) None of these

52. To study unstained living tissues, the microscope used is:
(a) Phase contrast microscope
(b) Electron microscope
(c) Fluorescence microscope
(d) None of the above

53. The source of illumination in SEM is:
(a) Ordinary daylight (b) Infrared rays
(c) Beam of electrons (d) Ultraviolet rays

54. Materials are separated by density gradient by centrifugation on the basis of:
(a) Size (b) Density
(c) Size and density (d) None of these

55. Resolving power of human eye is:
(a) 50 μ (b) 100 μ
(c) 200 μ (d) 150 μ

56. The order of sedimentation of subcellular structures during differential centrifugation is:
(a) Lysosome, mitochondria, ribosome
(b) Mitochondria, nucleus, lysosome

(c) Nucleus, mitochondria, lysosome
(d) Ribosome, nucleus, mitochondria

57. Which of the stains is used by the students in the laboratory for cytological studies?
(a) Safranin (b) Acetocarmine
(c) Fast green (d) Cotton blue

58. Which element of tissues is stained with safranin?
(a) Starch (b) Cellulose
(c) Lignified element (d) Protein

59. Pectic substances are generally stained with:
(a) Light green (b) Iodine
(c) Methylene blue (d) Cotton blue

*60. A student wants to study metaphasic behaviour of chromosomes. The technique most suitable is:
(a) Phase contrast microscope
(b) X-ray microscope
(c) Cell fractionation
(d) Scanning electron microscope

61. Binding of specific proteins on regulatory DNA sequences can be studied by means of: (CBSE 1993)
(a) Ultra centrifugation (b) Electron microscope
(c) X-ray crystallography (d) Light microscope

62. Transparent living cells can be properly studied under the microscope called:
(a) Ordinary optical microscope
(b) Electron microscope
(c) X-ray microscope
(d) Phase contrast microscope

63. Magnification of a compound microscope does not depend upon: (CBSE 1990)
(a) Focal length of objective
(b) Focal length of eyepiece
(c) Tube length of microscope
(d) Numerical aperture of objective

64. Dark field microscopy is used to detect bacteria. It makes use of: (AIIMS 1991)
(a) Invisible far-light (b) Invisible UV light
(c) Visible light (d) Does not use any light

65. One nanometre is equal to:
(a) 10^{-12} m (b) 10^{-6} m
(c) 10^{-3} m (d) 10^{-9} m

66. Which of the following is a basic stain?
(a) Methylene blue (b) Safranin
(c) Both (a) and (b) (d) Acid fuchsin

67. Which of the following is used for vital staining of the components of a living cell?
(a) Wright's stain (b) Malachite green
(c) Safranin (d) Acetocarmine

68. X-ray crystallography is used to study:
(a) Arrangement of proteins
(b) Composition of proteins and nucleic acid
(c) Three dimensional structure of proteins
(d) Structure of lipids

69. Which of the following is an acid stain?
(a) Methylene blue (b) Safranin
(c) Aniline blue (d) Basic fuchsin

70. Pure fractions of cellular components can be obtained by:
(a) X-ray diffraction
(b) Chromatography
(c) Differential centrifugation
(d) Microspectrophotometry

71. The feulgen nuclear reaction includes the following: (AIIMS 1990)
(a) Removal of purines at the level of the purine deoxyribose glucosidic bond of DNA by hydrolysis
(b) Reaction of the deoxyribose with leucofuchsin to give purple colour to DNA
(c) Reaction of the free aldehyde groups with Schiff's reagent to stain DNA
(d) Both (a) and (c)

72. Autoradiography technique was used to:
(a) Find out the absorption maximum of chlorophyll pigments
(b) Study photorespiration in some plants
(c) Trace the path of carbon in photosynthesis
(d) Establish that the oxygen evolved during photosynthesis is by photolysis of water molecules

73. Techniques by which subcellular components are separated on the basis of physical properties: (CPMT 1990)
(a) Electrophoresis (b) Cell fractionation
(c) Autoradiography (d) Chromatography

74. An individual organelle can be separated from a cell homogenate through:
(a) Chromatography (b) Differential centrifugation
(c) X-ray diffraction (d) None of these

75. Which of the following is/are isotopes?
(a) C^{14} (b) P^{32}
(c) H^{3} (d) All of these

76. Who among the following scientists developed cytochemical technique for the presence of DNA?
(a) Johannsen (b) Feulgen and Rossenbeck
(c) McClintock (d) Hammerling

77. For the location of cell organelles, the use of stains is termed as:
(a) Cytology (b) Chromatography
(c) Microscopy (d) Histochemistry

78. In cytoplasmic staining the substances used are:
(a) Fluorescent dyes (b) Colourless precursors
(c) Oil soluble stains (d) Ordinary stains

79. Which statement is correct for the microsome?
(a) Microsomes are discrete entities found only in nucleolus and revealed by electron micrographs
(b) Microsomes are not found in intact cells as discrete entities but result from the fragmentation of cytoplasmic membrane components
(c) Microsomes are discrete entities always found attached to the outer surface of rough ER
(d) Microsomes are discrete entities found in all living cells uniformly distributed throughout the cell

80. Which technique is used for locating an enzyme in sections of a material under microscope?
(a) By employing phase difference light
(b) By staining with benzidine

(c) By cytochemical staining
(d) By staining with methylene blue.

81. If a biochemical analysis of mitochondria is to be done, the best procedure would be to:
(a) Grind the cell and filter out the mixture and take the debris
(b) Subject the cells to cell fractionation
(c) Select cells which have a large number of mitochondria
(d) Plasmolyse the cells, filter it and take the debris

82. Homogenisation is:
(a) Separation of different cellular components
(b) Crushing of tissue to separate cells
(c) Separation of different cellular components
(d) Breaking of cells and then suspending in 0.25 M sucrose solution

83. Which process is determined by the use of C^{14} uridine?
(a) Photosynthesis (b) RNA synthesis
(c) DNA synthesis (d) Carbohydrate synthesis

84. In which of the following units the sedimentation coefficient of a subcellular particle is expressed? (BHU 1998)
(a) gm mL^{-1} (b) Newton (c) Svedberg (d) Dalton

85. Which method is used to trace a certain compound within a cell?
(a) Autoradiography
(b) Electron microscopy
(c) Phase contrast microscopy
(d) Staining

86. Why can the living cells not be observed under electron microscopy?
(a) Tremendous voltage kills the cells
(b) Cells get killed during the preparation of material to study
(c) Dehydration of cells is a must to avoid water vapours which disturb the vacuum
(d) All the above three reasons

87. The electron microscope is better than a light microscope because electron microscope has: (CPMT 1993)
(a) Higher energy electrons (b) Greater focal lengths
(c) More magnifying power (d) Light energy is not used

88. Interference microscopy is used:
(a) To localise a cellular organelle
(b) To study cells and their components in a living state using phase difference of light rays
(c) For obtaining X-ray diffraction patterns of DNA
(d) For increasing resolving power of microscope

*89. The common fixative for electron microscopy is:
(a) C_2H_5OH (b) Picric acid
(c) Osmium tetroxide (d) $K_2Cr_2O_7$

90. Resolving power of a compound microscope is affected by:
(a) The numerical aperture of eye lens
(b) Numerical aperture of objective lens
(c) Both (a) and (b)
(d) None of the above

91. If the high power field of a microscope has a diameter of 0.5 mm, the apparent diameter of a cell that would fill the field would be about:
(a) 0.5 µm (b) 500 µm
(c) 50 µm (d) 5.0 µm

92. Resolving power of a light microscope using white light is: (DPMT 2003)
(a) 0.1 µm (b) 0.2 µm
(c) 0.25 µm (d) 0.3 µm

93. The wavelength of radiations used in electron microscope is:
(a) Less than visible light (b) More than visible light
(c) Equal to visible light (d) Like the X-rays

94. The maximum resolution that can be obtained by a light-microscope using blue light is:
(a) 0.4 µm (b) 0.3 µm
(c) 0.2 µm (d) 0.1 µm

95. We require this instrument to see chromosomes in a living cell: (CET Karnataka 1993)
(a) Light microscope
(b) Electron microscope
(c) Phase contrast microscope
(d) Ordinary lens

96. What is the value of angstrom in metre? (CPMT 1993)
(a) 10^{-10} (b) 10^{-9}
(c) 10^{-8} (d) 10^{-5}

97. Nanometre is the other name of:
(a) Millimicron (mµ) (b) Micron (µ)
(c) Micrometre (µm) (d) Angstrom (Å)

98. A phase contrast microscope is used to:
(a) Localize cell structure stained with fluorochromes
(b) To study cells and their components in a living state using a phase difference in the light rays
(c) For increasing resolving power
(d) For obtaining X-ray diffraction pattern of DNA

99. Interference microscope was invented by:
(a) Merten *et al* (b) Knoll and Ruska
(c) Leeuwenhoek (d) Zernike

100. To improve the resolution of light microscope upto 1.5 times, we have to use:
(a) Red light + immersion oil between the specimen and objective
(b) Blue light + immersion oil between the specimen and objective
(c) Blue light + glycerine between the specimen and objective
(d) None of the above

101. Maximum magnifications of scanning electron microscope (SEM) are usually around:
(a) 200 times (b) 2,000 times
(c) 20,000 times (d) 2,00,000 times

102. To study the physiological function of a cell organelle, the method used is:
(a) Autoradiography (b) Fractionation
(c) Electron microscopy (d) None of these

103. The finest resolution achieved with a light microscope in visible light with oil immersion and without oil immersion is respectively:
(a) 3.0 µm and 30 µm (b) 0.3 µm and 10 µm
(c) 3.0 µm and 2.0 µm (d) 0.2 µm and 0.3 µm

104. To destruct cell boundary the tissues are homogenized in:
(a) 0.25 M sucrose solution (b) 1.0 M sucrose solution
(c) 1.0 M salt solution (d) 0.25 M salt solution

105. FAA is:
(a) A fungicide (b) A mutagen
(c) An amino acid (d) A fixative

106. During ultracentrifugation of cell homogenate, what fraction would be separated at 10,000 g × 20 minutes?
(a) Mitochondria and Lysosome
(b) Ribosome and Microsome
(c) Nucleus and Mitochondria
(d) Endoplasmic reticulum

107. Iodine test was developed by:
(a) Feulgen and Rossenbeck (b) F.V. Raspail
(c) Zernike (d) Fleming and Brown

108. Thin sections (20–100 nm) for electron microscopic studies are made with the help of:
(a) Ultramicrotomes (b) Razors
(c) Glass knife (d) None of these

109. The process of disrupting cells of a tissue is called:
(a) Centrifugation (b) Homogenisation
(c) Both (a) and (b) (d) None of these

110. The technique of chromatography was developed by:
(a) W. His
(b) Michael Tswett
(c) Feulgen and Rossenbeck
(d) Zernike

111. Resolving power of human eye, light microscope and electron microscope is respectively:
(a) 45 μ, 1700 μ, 2,00,000 Å
(b) 100 μ, 1/100 μ, 10 Å
(c) 200 μ, 1/100 Å, 5 Å
(d) 100 Å, 500 Å, 1,00,000 Å

112. Microtome, a device used for cutting ultra thin sections was invented by:
(a) Wilkins (b) Watson and Crick
(c) W. His (d) M. Tswett

113. Microscopy useful for studying highly ordered structures like spindle fibre is:
(a) Autoradiography (b) Chromatography
(c) Polarizing microscope (d) X-ray diffraction

114. Microscopy used for studying mitotically dividing cells:
(a) Nomarski interference (b) Fluorescence microscope
(c) Polarizing microscope (d) None of these

115. The technique used to study the fine details of surface features of cell organisms is:
(a) Transmission electron microscope
(b) Scanning electron microscope
(c) Interference microscope
(d) Fluorescence microscope

116. Feulgen reaction, a technique developed by Feulgen and Rossenbeck to study or to stain (or a Feulgen reaction is a specific test for establishing the presence of): (BHU 1991; AIIMS 1992; AMU 1997)
(a) DNA (b) RNA
(c) Protein (d) Lipids

117. The resolution power of a microscope means the capacity to: (CBSE 1991)
(a) Magnify the image
(b) Distinguish between organelles
(c) Distinguish between two objects
(d) Distinguish between two points

118. A DNA molecule in *E. coli* is heavy (fully labelled with N^{15}) and is allowed to replicate in a medium containing N^{14}; after one generation of replication, the two daughter molecules: (CBSE 1992)
(a) Will be similar in density, but will differ from that of parent DNA
(b) Will differ in density from one another and also from that of parent DNA
(c) Will have the same density as that of the parent DNA
(d) Will differ in density from one another, but will resemble the parent molecule

119. The techniques used for separating DNA fragments is: (DPMT 1991; AIIMS 1993)
(a) Southern blotting (b) Northern blotting
(c) Western blotting (d) Eastern blotting

*120. DNA synthesis can be specifically measured by estimating the incorporation of radioactive labelled: (CBSE 1997)
(a) Uracil (b) Thymidine
(c) Adenine (d) Deoxyribose sugar

121. Which of the following types of microscope uses UV-rays of higher wavelength: (AMU 1991)
(a) Ultraviolet microscope (b) Fluorescence microscope
(c) Polarizing microscope (d) Electron microscope

122. To determine the ultrastructure of a cell organelle the most likely method to be used would be: (AIIMS 1997)
(a) Phase contrast microscope
(b) Light microscope
(c) Electron microscope
(d) Micro dissection

123. The fragments of endoplasmic reticulum are known as: (BHU 1991)
(a) Lysosomes (b) Spherosomes
(c) Microtubules (d) Microsomes

*124. If we want to have T_2 bacteriophage with protein coats incorporating S^{35}, then the best procedure would be: (AIIMS 1992)
(a) To grow T_2 phages in a medium containing S^{35} labelled amino acids
(b) Introduce a single T_2 phage into a bacteria like *E. coli* containing S^{35} labelled protein
(c) Produce a single T_2 phage with S^{35} labelled protein coat, then allow it to divide in an *E. coli*
(d) None of the above

125. The electron microscope differs from the ordinary light microscope in having high resolving power due to the use of: (CBSE 1992)
(a) Electrons, which have a longer wavelength than the ordinary light rays, as the source of illumination
(b) Fast electrons, which have a shorter wavelength than of the ordinary light rays, as the source of illumination
(c) Gamma rays as the source of illumination
(d) UV-rays as the source of illumination

*126. The most significant drawback in electron microscope is that: (AIIMS 1993)
(a) It is very costly
(b) It requires high technical skill
(c) It is to be lodged in vacuum
(d) Living cells cannot be observed under it

127. Which rays are used for making image for CT scan? (CET Chandigarh 1992)
(a) X-rays
(b) Positron emitting from radiographs
(c) Hydrogen ions
(d) Ultrasound waves

128. Which microscope would you require if asked to examine a culture of unstained living and dividing cells? (AIIMS 1993; Manipal 1997)
(a) Scanning electron microscope
(b) Transmission electron microscope
(c) Phase contrast microscope
(d) Polarization microscope

*129. In recent years, considerable attention is being given to DNA-protein interactions, because expression of genes is regulated through binding of specific proteins on regulatory DNA sequences. The pattern of protein binding of DNA can be studied by: (CBSE 1993)
(a) Ultracentrifugation (b) Light microscope
(c) X-ray crystallography (d) Electron microscope

130. Semiconservative mode of DNA replication was first reported in *E. coli* with the help of N^{15}, a heavy nitrogen isotope by: (MPPMT 1996; BHU 1997)
(a) Watson and Crick (b) Meselson and Stahl
(c) Kornberg and Ochoa (d) Luria and Delbruck

131. The technique used to determine the spatial arrangement of atoms in the molecular structure of macromolecules is: (BHU 1996)
(a) Autoradiography (b) X-ray crystallography
(c) Spectrophotometry (d) Chromatography

*132. Which one of the following is labelled with H^3 to study RNA synthesis? (AIIMS 1997)
(a) Thymidine (b) Uridine
(c) Cytosine (d) Guanosine

133. Feulgen's positive reaction is the test for: (DPMT 1997)
(a) RNA (b) Proteins
(c) Lipids (d) DNA

134. The technique used for estimation of minor amounts of hormones and drugs is called: (CBSE 1999)
(a) Electrophoresis (b) Electroencephalogram
(c) Fractionation (d) Radioimmunoassay

135. Mitochondria can be stained by: (BHU 1999)
(a) Cobal fuchsine (b) Saffranine
(c) Methylene blue (d) Janus green

136. Half-life period of C^{14} is: (CBSE 2001)
(a) 500 years (b) 5000 years
(c) 50 years (d) 5×10^4 years

137. Vital stains are employed in the study of:
(a) Living cells (b) Dead cells
(c) Both (a) and (b) (d) None of these

138. Cell surfaces and objects of larger size can be studied with the help of:
(a) TEM (b) SEM
(c) Polarizing microscope (d) None of these

139. Dye used in Feulgen's test for detection of DNA is:
(a) Janus green (b) Basic fuchsine
(c) Methylene blue (d) Acetocarmine

140. The most commonly used homogenisation medium is:
(a) 0.25 M sucrose solution (b) Litmus solution
(c) NaCl solution (d) Cesium chloride solution

141. Electron microscope is used for: (Kerala PMT 2003)
(a) Viewing structure of the cell
(b) Whole mount study
(c) Cell division study
(d) Structure of pollen grain
(e) Structural details of large biomolecule

142. Sub-cellular components are separated by: (Jharkhand CECE 2003)
(a) Electrophoresis (b) Cell fractionation
(c) Chromatography (d) Autoradiography

ANSWERS

1—c	2—b	3—b	4—c	5—a	6—a	7—c	8—c	9—a	10—c	11—a	12—c
13—d	14—d	15—a	16—b	17—c	18—c	19—d	20—a	21—a	22—d	23—c	24—c
25—c	26—b	27—c	28—a	29—c	30—a	31—c	32—b	33—c	34—d	35—d	36—a
37—d	38—b	39—a	40—b	41—c	42—c	43—b	44—c	45—c	46—c	47—d	48—c
49—c	50—a	51—c	52—a	53—c	54—b	55—b	56—c	57—b	58—c	59—c	60—a
61—c	62—d	63—d	64—c	65—d	66—c	67—b	68—c	69—c	70—c	71—d	72—c
73—b	74—b	75—d	76—b	77—d	78—b	79—b	80—c	81—b	82—d	83—b	84—c
85—a	86—d	87—a	88—b	89—c	90—b	91—b	92—c	93—a	94—c	95—c	96—a
97—a	98—b	99—a	100—b	101—c	102—b	103—d	104—a	105—d	106—a	107—b	108—a
109—b	110—b	111—b	112—c	113—c	114—a	115—b	116—a	117—c	118—a	119—a	120—b
121—b	122—c	123—d	124—b	125—b	126—d	127—a	128—c	129—c	130—b	131—b	132—b
133—d	134—d	135—d	136—b	137—a	138—b	139—b	140—a	141—a	142—b		

EXPLANATION OF SELECTED QUESTIONS (*)

4. Condenser lens, objective lens and ocular lens are 3 lenses in a compound microscope.
14. Electron microscope is made of electromagnetic lenses.
60. In phase contrast microscope, the living cells and tissues can be studied without fixing and staining them, *e.g.*, chromosomes in a living cell.
89. The most common fixatives for electron microscopy are glutaraldehyde and osmium tetroxide.
120. Thymine (T) is the characteristic N-base of DNA (A, G and C are present in both RNA and DNA).
124. Bacteriophages are obligate parasites and can live and multiply inside living bacterial cells only.
126. The most significant drawback of electron microscope is that living cells cannot be observed under it because a very high voltage (50,000 V) is required to produce the electron beam (source of light), which kills living cells.
129. Arrangement of atoms in molecular structure of enzymes, proteins and DNA, etc., can be studied by X-ray crystallography.
132. Uracil (U) is the characteristic N-base of RNA. Its nucleotide is uridine monophosphate.

4

Structural and Functional Organization of Cell

- Meaning of cytology and brief history
- Cell theory
- Size, number, shape and types of cells
- Differences between prokaryotic and eukaryotic cells
- Organization (structure) of cell
- Cell wall
- Plasma membrane or cell membrane
- Vacuole
- Protoplasm
- Cytoplasmic organelles or Metabolically active organelles—Mitochondria, Plastids (Chloroplasts, Leucoplasts and Chromoplasts), Endoplasmic reticulum, Golgi complex, Ribosomes, Microbodies (Lysosomes, Peroxisomes, Sphaerosomes and Glyoxysomes, etc.), Centrosome, Cilia and Flagella, Cytoskeleton (Microtubules, Microfilaments, Intermediate filaments)
- Nucleus—Chromosomes
- Metabolically inactive substances or Deutoplasmic substances
- Differences between plant and animal cell

Cytology (Greek : *Kytos* - cell + *Logos* - study) is the branch which comprises the study of cell structure and function.

- **All living organisms** (plants and animals) are composed of repeated **structural units called cells.** Each cell is independent in performing all necessary processes of life and is the least complex unit of matter which can be called living.
- **Robert Hooke** (1665) discovered **hollow cavities** in a thin piece of bottle cork under very light microscope and the term cell (Latin, *Cella,* hollow cavity) has been given to these cavities by him. Actually these so called cells were cell walls and original photographs of these are present in '**Micrographia**'.
- **Grew** and **Malpighi** observed some hollow cavities surrounded by cellulosic walls in different materials, *i.e.*, actual cells. Leeuwenhoek (1674) observed free cells with an improved microscope and upto some extent observed the internal organization of the cells.

CELL THEORY

- **H.J. Dutrochet** (1824) a French worker gave the idea of cell theory. He boiled *Mimosa* in nitric acid and separated the cells.
- Actual credit of the cell theory goes to two Germans, a botanist Schleiden and a zoologist T. Schwann (1839). The concept that **"All living organisms are composed of cells"** is known as cell theory.
- R. Virchow (1859) extended this theory and said *"Omnis cellula e cellula"*, *i.e.*, all cells arise from the pre-existing cells.

Main components of cell theory

(i) All living beings are composed of cells.
(ii) All cells arise from the pre-existing cells.
(iii) All cells are basically similar in chemical composition and metabolism.
(iv) All living beings function because of the activities and interaction of these cells.

Exceptions to the cell theory

- Viruses are an exception to the cell theory as they are obligate parasites (subcellular in nature). *Paramoecium, Rhizopus, Vaucheria* are some examples which may or may not be exceptions to the cell theory.

SIZE, NUMBER, SHAPE AND TYPES OF CELLS

Cell size

Generally the cell size ranges between 0.2–20 μ.

- The **smallest cell** so far observed is considered to be of PPLO (pleuropneumonia like organism) or *Mycoplasma gallisepticum, i.e.*, 0.1 μ.
- The **largest cell** is an egg of ostrich which measures as much as 6 inches in diameter with shell and 3 inches without shell.
- The **bacteriophages** or **viruses** are still smaller in size (but cannot be considered as cells because of **sub-cellular nature**).

1839

- *Acetabularia*, a unicellular green alga is about 10 cm in length.
- In the alga *Caulerpa* (Siphonales) the length of cell may be upto **one metre.**
- Fibres of ramie are about 50–55 cm long.
- In animals nerve fibres are the longest, upto 90 cm to few metres.

Some Important aspects

- Metabolically active cells are smaller in size.
- Cell size ∝ chromosome number.
- Cells of a particular type have almost same volume.

Cell number

There is a wide range in number of cells ranging from a single cell in unicellular organisms to indefinite cells in multicellular forms.

- Unicellular organisms have single cell, *e.g.*, yeast, diatoms, etc.
- In multicellular organisms, number is not definite, *e.g.*, a man of 80 kg has about **60 thousand billion cells.**
- In green alga *Pandorina*, the colony is having a fixed number of cells (8, 16 or 32). *Eudorina*, another green alga, has a colony of (16, 32 or 64) cells.

Cell shape

There is great variability in cell shape, *i.e.*, **spherical, polygonal, disc-like, cuboidal, columnar, spindle-like,** etc. **Individual cells are generally ball-like (spherical) but due to mutual pressure they become polyhedral.**

- Shape of the cell sometimes changes because of the function, *e.g.*, **Amoeba and Leucocytes,** etc.

Types of cells

Depending upon the nature of the nucleus, cells are of two types:

(i) **Prokaryotic cells** (Greek: *Pro* – primitive + *Karyon*-nucleus).

Here primitive or ill defined or incipient nucleus is present, *e.g.*, in bacteria, blue-green algae (myxophyceae or cyanophyceae or cyanobacteria) and PPLO (Pleuropneumonia like organisms) or mycoplasma, *i.e.*, akaryobionta.

- The most extensively studied prokaryote is *E. coli* (*Escherichia coli*), a common bacterium found in intestine of human beings.

(ii) Eukaryotic cells (Greek: *Eu* – good or well + *Karyon*-nucleus).

Cells with true or well defined nucleus with membrane are eukaryotic cells, *e.g.*, higher plants and animals (karyobionta).

- Prokaryote and eukaryote terms were given by **Chatton.**
- In members of class **Dinophyceae** of algae (*e.g.*, *Desmocapsa, Desmomastix, Dinophysis, Heterocapsa, Dinothrix*, etc.), there is present an intermediate type of cell organization called **Mesokaryotic.** Here, there is present a true or eukaryotic nucleus with definite nuclear membrane and chromosomes (eukaryotic characters), but chromosomes are not well organized as basic proteins or histones are absent (prokaryotic feature).
- Clear optically homogeneous fluid part of cytoplasm after removal of organelles or particulate components is called **Cytoplasmic Matrix or Cytosol or Hyaloplasm or Groundplasm.** It is made of 90% water in which different substances (like proteins, enzymes, starch, fat, minerals, etc.) are present in the form of true solution and colloidal solution.

Size, number & shapes

structural & functional organization of cells

DIFFERENCES BETWEEN PROKARYOTIC AND EUKARYOTIC CELLS

	Prokaryotic	Eukaryotic
1.	Nuclear membrane or envelope is absent.	Nuclear membrane is present.
2.	DNA is naked, *i.e.*, not combined with proteins. Histones are altogether absent.	DNA is combined with proteins (histones as well as non-histones).
3.	Single naked chromosome is present in Prokaryotes.	Multiple chromosomes are present.
4.	Nucleolus is absent.	Nucleolus is present.
5.	Ribosomes are of 70S type (50S + 30S).	Ribosomes are of 80S type (60S + 40S).
6.	Mitochondria are absent (respiratory enzymes on plasma membrane).	Mitochondria are present.
7.	Endoplasmic reticulum, Golgi bodies, centrioles, lysosomes and other microbodies are absent.	These all are present.
8.	Exocytosis and endocytosis are absent.	Both are present.
9.	Flagellum single stranded, *i.e.*, only one fibril is present.	Generally 9+2 pattern is present.
10.	Cell size is 100-2,000 nm (1000 Å–20,000 Å).	10,000–1,00,000 nm.

ORGANIZATION OF CELL

cyto + nucleus = protoplasm

- CELL
  - Cell wall and plasma membrane (in plant cell)
    - cytoplasmic membrane (in animal cells -
  - Vacuole (in plant cell only)
  - Protoplasm
    - Cytoplasm
      - Metabolically active organelles or Cytoplasmic organoides or Cytoplasmic organelles
        1. Mitochondria ⎤ Semi-autonomous bodies
        2. Plastids ⎦
        3. Endoplasmic reticulum
        4. Golgi bodies
        5. Ribosomes
        6. Centrosomes
        7. Microbodies i.e., Lysosomes, Peroxisomes, Glyoxysomes, Sphaerosomes, etc.
      - Metabolically inactive substances or Cytoplasmic inclusions or Ergastic substances or Deutoplasmic substances or Deutoplasm
        - Storage substances *e.g.*, Carbohydrates, Fats, Proteins, etc.
        - Secretory substances *e.g.*, Colouring matter, Enzymes, Nectar, etc.
        - Excretory substances *e.g.*, Glucosides, Tannins, Gums, Resins, etc.
    - Nucleus

CELL WALL

In all plants including bacteria a rigid cell wall is present on the surface. It is lined internally throughout by cell membrane or plasma membrane.

- The presence of cell wall in plants is the main difference between plant and animal cell.
- The cell wall varies in thickness from 0.1 μm to 10 μm in different cells.
- Generally in most of the cases, cell wall is present from the very beginning but in slime fungi (myxomycetes) cell wall is present for a very short time.

Composition

- In plants, cell wall is made up of **cellulose** (β-D-glucose units), **hemicellulose** (arabinose, mannose, xylose, galactose, etc.) and **pectin** (galactose, galacturonic acid and arabinose).
- In bacteria, cell wall is composed of protein-lipid-polysaccharides having two important chemical components: N-acetyl glucosamine (NAG) and N-acetyl muramic acid (NAM).
- In fungi, cell wall is made up of **chitin** (polymer of N-acetyl glucosamine).

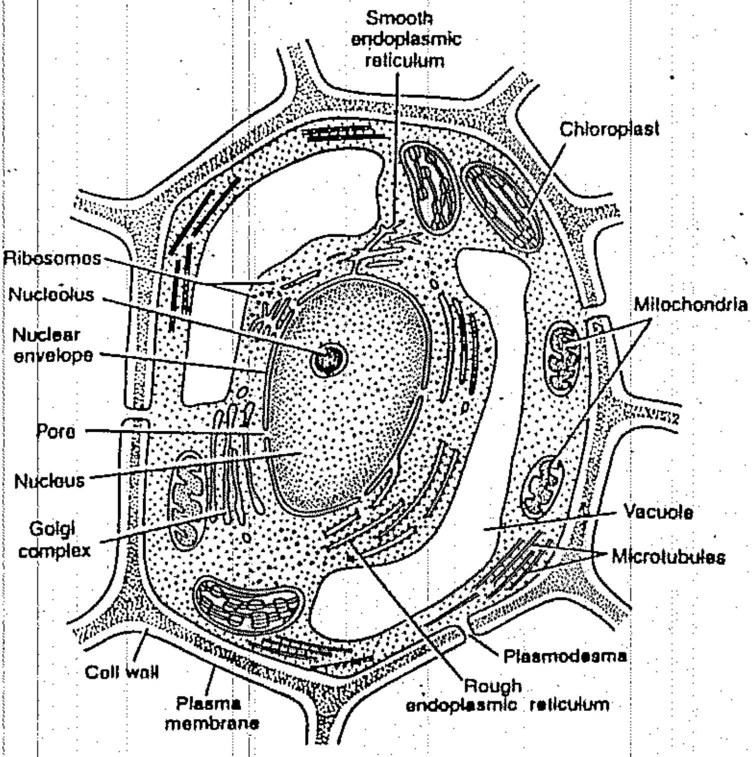

Smooth endoplasmic reticulum
Chloroplast
Ribosomes
Nucleolus
Nuclear envelope
Mitochondria
Pore
Nucleus
Vacuole
Golgi complex
Microtubules
Plasmodesma
Cell wall
Plasma membrane
Rough endoplasmic reticulum

Fig. 4.1. Structure of a plant cell

β.D-Glucose units.

Morphology

A typical cell wall is made up of 4 layers, namely:

(i) **Middle lamella:** It is the cementing layer between the cells. It is made up of Ca and Mg pectates.

- o **The ripened fruits** become softened due to dissolution **of middle lamella.** It can be done artificially by spraying strong acids. HCl

(ii) **Primary wall:** It is laid down on both sides of middle lamella. Primary wall is elastic in nature. It is made up of cellulose, hemicellulose, pectic substances, etc. It is about 1–3 μm thick.

(iii) **Secondary wall:** It is laid down on the inner side of primary wall after the growth of cell stops (at maturity). It is 5–10 μm thick, rigid and non-elastic, made up of cellulose (sometimes hemicellulose) and lignin.

- Growth of cell wall occurs by two methods:
  - (a) **By Intussusception:** The primary wall is stretched and materials of secondary wall are deposited.
  - (b) **By Apposition:** Materials of secondary wall are deposited in the form of thin layers.

(iv) **Tertiary wall:** Sometimes tertiary wall is laid down on secondary wall, *e.g.*, **tracheids of gymnosperms.** It is purely cellulosic in nature.

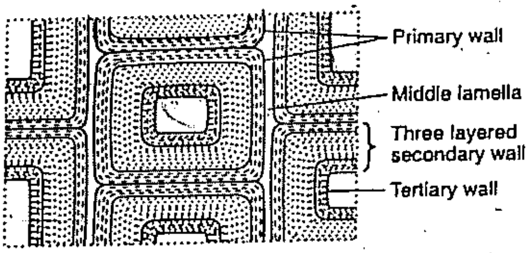


Fig. 4.2. Structure of cell wall

Pits

The cell wall is not uniform in thickness throughout; at certain places secondary wall or both primary and secondary walls are not laid down. Such places are called pits.

Pits are of two types:

(i) **Simple pit** in which pit chamber is uniform in diameter.

(ii) **Bordered pit** in which pit chamber is flask-shaped in tracheids of gymnosperms and vessels of angiosperms.

Plasmodesmata: A number of plasmodesmata or cytoplasmic strands are present in pit through which the cytoplasm of one cell is in contact with another. Endoplasmic reticulum plays a role in origin of plasmodesmata.

- **Tangle** (1879) first of all discovered plasmodesmata and were studied elaborately by Strasburger (1901).

Ultrastructure

After maceration it has been found that cell wall consists of two main parts: **Fibrils and Matrix.**

A net-like framework of macrofibrils is embedded in an amorphous, gel-like material, the matrix.

- Each macrofibril is 1 μm in diameter and made up of 250 microfibrils. Each microfibril is 300 Å thick and made up of 20 micelle or elementary fibrils. These micelle are visible under electron microscope.

  A single micelle is 35 Å–100 Å thick and made up of 100 chains of cellulose molecules. Each cellulose chain is made up of a number of interlinked β-D-glucose molecules in a linear fashion.

- The fibrils are arranged in a net-like fashion to form a lamella, several lamellae form a layer and several layers form a wall.

Origin of cell wall

Origin of cell wall takes place from cell plate during cytokinesis. Many cell wall vesicles provided by Golgi bodies and endoplasmic reticulum combine to form a cell plate. After some chemical and physical changes, the cell plate grows on both sides to form a middle lamella. Primary and secondary walls are laid down on middle lamella to form cell wall. Beside these, different materials are deposited as:

(i) **Lignin:** It is special type of polysaccharide which deposits mainly in xylem cells and makes them hard and lignified. Due to its deposition xylem tracheids take up different forms, *e.g.*, annular thickening, spiral thickening, scalariform thickening.

(ii) **Suberin:** It is a complicated mixture of fatty acids deposited on cork cells. Suberin is impermeable to water.

(iii) **Cutin:** It is a wax-like fatty substance. It is deposited on the epidermal cells in the form of cuticle which reduces loss of water. Cuticle is very thick in xerophytes, thin in mesophytes and absent in hydrophytes.

(iv) **Silica:** In some cases sand or silica particles are deposited which give a rough touch, *e.g.*, *Equisetum* and *Saccharum munja*.

- o In family Moraceae, Urticaceae, Cucurbitaceae and Acanthaceae, Ca oxalate and Ca carbonate crystals are deposited.

(v) **Mucilage:** Some cells are slippery to touch due to secretion of mucilage, *e.g.*, blue-green algae. The cells can withstand extremes of temperature, *i.e.*, very low or very high.

Intercellular spaces

Young cells are completely packed with no intercellular spaces but in mature cells, certain spaces (cavities) are produced which are of 3 types:

(i) **Schizogenous cavities** (*Schizein*—to split): In mature cells, the cell walls separate from each other and form a cavity, *i.e.*, schizogenous cavity, *e.g.*, resin canal in *Pinus*.

(ii) **Lysigenous cavities** (*Lysis*—breakdown): It is formed by the breakdown (dissolution) of cell walls, *e.g.*, *Citrus* oil cavities.

(iii) **Schizo-lysigenous cavities:** Both the above processes are involved here, *e.g.*, protoxylem of maize.

Functions

The main function of cell wall is to provide mechanical strength, particularly in higher plants having vascular system. It provides the main supporting framework in plants as the skeleton in animals, *i.e.*, exoskeleton.

PLASMA MEMBRANE OR CELL MEMBRANE

Cell surface in all the cells is enclosed by a **living membrane** which is called cell membrane by **C. Nageli** and **C. Kramer** (1855). **J.Q. Plower** (1931) coined the term **Plasmalemma** for cell membrane.

In a plant cell, the dead cell wall is present at the outer side of plasma membrane.

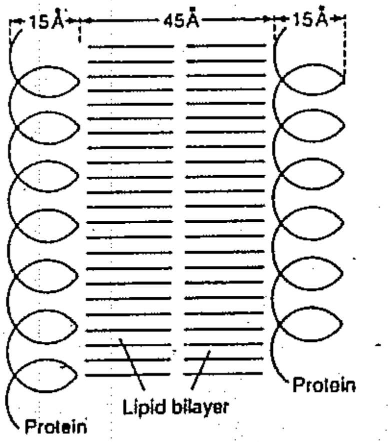


Fig. 4.3. Robertson's unit membrane model of plasma membrane

Chemical composition

The chemical composition of plasma membrane includes mainly three components:

(i) **Proteins** are the major component, forming 60% of the plasma membrane. They not only provide mechanical strength but are also responsible for transportation of different substances. Proteins also act as enzymes.

(ii) **Lipids** account for 28–79% depending upon the type of cell and organism involved (in humans, Myelin, 79%). Because of the presence of lipids, membranes are always continuous, unbroken structures and are deformable and their overall shape can change (during cell division or locomotion). Further, lipids facilitate the fusion and splitting of membranes.

- **Mainly phospholipids, galactolipids and cholesterol** are present.

(iii) **Carbohydrates** form 5% (2–10%). Oligosaccharides are the main carbohydrates present in plasma membrane. The carbohydrates of plasma membrane are covalently linked to both lipid and protein components. In glycoproteins, the carbohydrate is present in the form of short, branched oligosaccharide chains. Common sugars of these chains are D-glucose, D-mannose, D-galactose, N-acetylglucosamine, N-acetyl galactosamine and N-acetyl neuraminic acid or sialic acid.

- Generally the terminal sugar of oligosaccharides is **Sialic acid.**
- All carbohydrates of plasma membrane face outward into extracellular space or away from cytosol.

Cholistrol

Ultrastructure

Under electron microscope the plasma membrane appears three layered, *i.e.*, **trilaminar.** One optically light layer is of lipids and on both sides of it two optically dense layers of proteins are present.

Generally the plasma membrane is 75 Å **thick.** Light layer is 45 Å **thick,** while dark layers are 15 Å + 15Å in thickness. This structure is called **unit membrane by Robertson** (1959).

Molecular structure

Regarding the molecular structure of plasma membrane different models have been given.

Sandwich Model was proposed by **Davson** and **Danielli** (1935, 52). According to this model the light bimolecular lipid layer is sandwiched between two dense protein layers (one on either side). The inner ends of lipid molecules are hydrophobic and non-polar while the outer ends are hydrophillic and polar. Proteins are attached at the outer ends of lipid layer (hydrophillic ends) by **ionic exchanges** and **hydrostatic forces.**

These concepts of Davson and Danielli were formulated by Robertson (1950) to give the famous **Unit Membrane Model.**

Now it has been well established that in plasma membrane proteins are of two types:

(i) **Extrinsic proteins** are peripheral proteins, associated with the surface. These can be easily removed, *e.g.*, spectrin in red blood cells and ATPase in mitochondria.

(ii) **Intrinsic proteins** or **Integral proteins** enter the lipid bilayer and extend all the way through it, *e.g.*, rhodopsin in retinal rod cells. The portions of the polypeptide chains that extend through the lipid bilayer typically occur as α-helices composed of hydrophobic amino acids.

Singer and **Nicolson** (1972, 74) gave the modern concept about the structure of plasma membrane, the **Fluid Mosaic Model,** according to which:

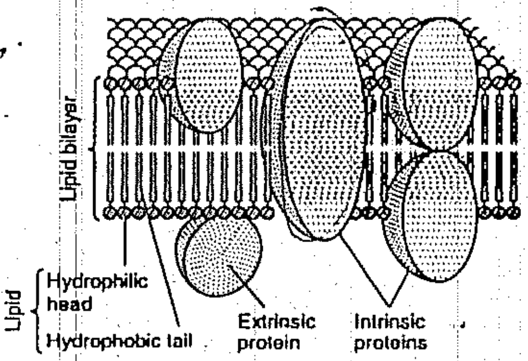


Fig. 4.4. Fluid mosaic model of plasma membrane structure.

(i) Lipids and intrinsic proteins form a mosaic pattern.

(ii) The membrane is semifluid in nature and hence the lipid molecules and intrinsic proteins move freely.

- Such membranes are also present around different cell organelles, *e.g.*, mitochondria, Golgi bodies, endoplasmic reticulum, etc.

Functions

(i) The most important function of plasma membrane is to provide passage for various substances, into and out of the cell.

(ii) Plasma membrane is selectively permeable, *i.e.*, allows some solute particles (1–15 Å) to pass through it readily along with all solvents.

(iii) It not only provides mechanical strength but also acts as a protective layer.

(iv) Plasma membrane is responsible for the transportation of materials, molecules or ions, etc., through it.

(a) **Exocytosis:** Molecules are taken out of the cell through this process.

(b) **Endocytosis** is ingestion of molecules either in solid form, *i.e.*, **phagocytosis** (cell eating) or in liquid form, *i.e.*, **pinocytosis** (cell drinking).

(c) **Active transport:** In this process chemical energy is required because molecules move against the normal diffusion gradient.

(d) **Passive transport:** Movement of molecules from the region of higher concentration to lower concentration.

(v) Diffusion of different gases takes place through plasma membrane.

(vi) Carbohydrate (oligosaccharide) molecules of cell membrane help in cell-to-cell recognition (*i.e.*, recognizing self from nonself).

mosaic pattern

Origin

Cytoplasm provides surface active substances at phase boundary which accumulate to form plasma membrane.

VACUOLE

In a plant cell, vacuole may be defined as a **non-living** reservoir, bounded by a differentially or selectively permeable membrane, the **tonoplast.** The structure of tonoplast is similar to that of single unit membrane, *i.e.*, tripartite structure.

- In a young cell, vacuoles are extremely small in size or may be absent. As the cell enlarges, these smaller vacuoles fuse and form a large central vacuole at maturity. So in a mature cell the protoplasm is present as a thin layer, pushed towards the wall of the cell. This thin layer of protoplasm is called as **primordial utricle.**
- Vacuole is not an air-filled cavity, rather it is filled with a highly concentrated solution called **vacuolar sap** or **cell sap.** This cell sap is generally neutral but at maturity it becomes acidic. It contains many dissolved solutes such as organic acids, soluble carbohydrates, soluble nitrogenous compounds as nitrates, enzymes, tannins, chlorides, phosphates, amino acids, alkaloids and anthocyanin pigments.

Anthocyanins: These pigments are responsible for the different colours of flowers, *i.e.*, violet, purple, blue, red or brown. Anthocyanins also occur in coloured roots, *e.g.*, beet root, in coloured stems, *e.g.*, balsam stem and in some variegated leaves of garden *Croton*, *Amaranthus* and in young red leaves of many plants, *e.g.*, mango.

Anthocyanins act as a shield for chloroplast and protoplasm against strong sunlight. They also act as insect attractants during pollination.

- Anthocyanins are soluble in water and alcohol and extracted on boiling in water.
- These pigments change their colour with change in pH of cell sap, *e.g.*, red in acidic medium and blue in alkaline.

Function of vacuole: Vacuole maintains osmotic relation of cells which is helpful in absorption of water, etc.

PROTOPLASM

Life is impossible without protoplasm, which is the living substance of the cell. Protoplasm is present in all living cells and performs all vital functions of a cell, hence, **J. Huxley** rightly defined it as '**Physical basis of life**'. **Dujardin** (1835) discovered it and named it as 'Sarcode'. **Purkinje** (1837) renamed it as 'Protoplasm'.

Hugo von Mohl (1844) gave the significance of protoplasm. Max Schultz (1861) gave the protoplasmic theory, *i.e.*, all living cells are made of protoplasm in which all the vital activities occur.

Physical properties of protoplasm

(i) Protoplasm is a complex, granular, elastic, viscous and colourless substance.

(ii) Protoplasm is selectively or differentially permeable.

(iii) **Cyclosis** or **streaming movements** are shown by protoplasm, which are of two types:

(a) **Rotation** in one direction, either clockwise or anticlockwise in *Hydrilla*, *Vallisneria*.

(b) **Circulation** in different directions in *Tradescantia*.

(iv) Protoplasm is considered to be a "polyphasic colloidal system". **Fischer** (1894) and **Hardy** (1899) showed its colloidal nature (Latin: *Kolla*, glue + *Eidos*, appearance).

The chief component of protoplasm is water. Various soluble substances such as glucose, minerals, etc., remain dissolved in water and form a **true solution** or **crystalloid.** In this solution various larger insoluble organic compounds such as fatty acids, proteins and some carbohydrates are suspended in the form of colloidal particles. The true solution acts as a **dispersion medium** whereas different colloidal particles such as proteins and lipids, etc., constitute **dispersed phase.**

Some emulsions or suspensoids are also present and hence protoplasm is a complex colloidal system of many phases.

Suspensoids.

Support in favour of the colloidal nature of protoplasm

(i) **Increased surface area and adsorption:** The colloidal particles present in protoplasm such as enzymes provide a large surface area for various chemical reactions to occur and also have a characteristic property of adsorption. The large protein molecules are hydrophillic in nature and adsorb water molecules.

(ii) **Sol-gel transformation:** Colloidal mixture may be fluid (sol) or viscous (gel). Sol $\rightleftharpoons$ Gel.

(iii) **High viscosity:** Shows its colloidal nature.

(iv) **Coagulability:** Some of the proteinaceous constituents of the protoplasm coagulate at high temperature (app. at 60°C or above) which results in the death of the cells.

(v) **Brownian movement:** There is zig-zag movement of molecules due to random collisions.

True sol.	Colloids	Suspension
0.001 μ	0.001 μ–0.1 μ	0.1 μ
or	or	or
10^{-7} cm–10^{-8} cm	10^{-5} cm–10^{-7} cm	10^{-3} cm–10^{-5} cm

Chemical composition

The exact chemical composition of protoplasm cannot be determined as it undergoes continuous changes and its composition is not, therefore, constant.

The approximate constitution of plant protoplasm is as follows:

Water	—	about 90%
Proteins	—	7.2%
Carbohydrates	—	2.0%
Fats	—	1.0%
Minerals	—	1.0%
DNA and RNA	—	in traces

- Maximum water content in protoplasm is found in hydrophytes, *i.e.*, 95%, whereas minimum in seeds, spores (dormant organs), *i.e.*, 10–15%. In animals water is less (about 65%) and proteins are more (about 15%).
- In plants, pH of protoplasm varies not only in different cells but from time to time in the same cell. Although plant protoplasm is less known and generally pH is on acidic side, but different vital activities occur at neutral pH which is considered as 7.
  In animals, nucleus is slightly alkaline (7.5–7.6 pH) whereas cytoplasm is slightly acidic (6.7–6.9 pH).
- Injury decreases the pH of the cell (*i.e.*, 5.2–5.5) and if it remains for a long time, the cell dies.

CYTOPLASMIC ORGANELLES

1. MITOCHONDRIA

Mitochondria are hollow, sac-like structures present in all eukaryotes except mature RBCs of mammals and sieve tubes of phloem. These are absent in all prokaryotes like bacteria and cyanobacteria (blue-green algae).

Mitochondria were first of all reported in striated muscles of insects by **Kollicker (1850)**. But the actual credit of the discovery of mitochondria goes to **Flemming** (as thread like structure) and **Altman** (as granular structure) **in 1900.**

- C. Benda (1897) gave the name Mitochondria (*Mitos*, thread + *Chondrion*, granules).
- In plant cells the mitochondria were discovered by Meves (1904) in *Nymphaea*.
- The term 'Bioplast' for mitochondria was used by **Altman.**
- A dye for staining mitochondria is **Janus green** (vital dye).

Number of mitochondria varies from single to several thousands.

- A single mitochondrion is present in unicellular green alga, *Microsterias*. Generally, the number of mitochondria varies from 50–50,000 per cell. In some protozoans the number reaches upto 5,00,000.
- Mitochondria of a cell are collectively known as **chondriome.**

Size of mitochondria: Varies from 3.0–5 μ in length and 0.2–2.0 μ in diameter.

Ultrastructure

Mitochondrion is bounded by two unit membranes separated by perimitochondrial space (6–10 nm wide), which contains a fluid having a few enzymes. The outer membrane is specially permeable because of presence of integral proteins called **porins**. The inner membrane is highly impermeable, so all molecules and ions require special transporters present in the inner membrane to get entry into the matrix. Further, the outer membrane is smooth whereas the inner membrane is folded or convoluted to form mitochondrial crests.

- In animal cells these foldings are plate-like and called **cristae**. In plants these foldings are tubular and called **tubuli** or **microvilli**.

On cristae on M-face, *i.e.*, matrix facing face there are present

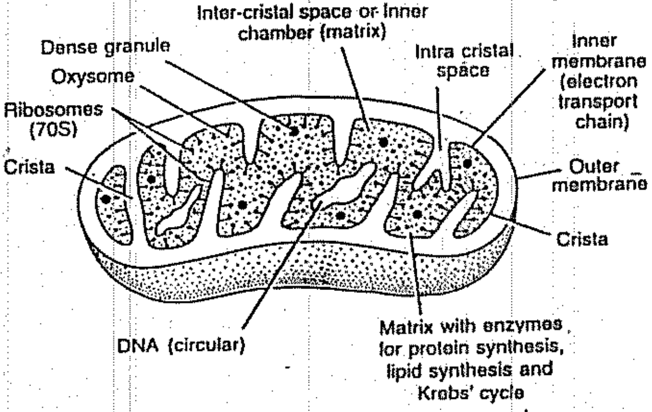

Inter-cristal space or Inner chamber (matrix)
Dense granule
Oxysome
Ribosomes (70S)
Crista
Intra cristal space
Inner membrane (electron transport chain)
Outer membrane
Crista
DNA (circular)
Matrix with enzymes for protein synthesis, lipid synthesis and Krebs' cycle

Fig. 4.5. Structure of a mitochondrion

some small stalked particles called oxysomes, or F_1 particles or elementary particles. Each particle is made up of base, stalk and head and is about 10 nm in length. The number of oxysomes per mitochondrion varies from 10^4–10^5. Chemically these are made up of phospholipid core and protein cortex. Oxysomes have ATPase enzyme molecules (Packer, 1967) and therefore, responsible for ATP synthesis. These elementary particles are also called **F_0–F_1 particles** by some workers. The base of these is called F_0 sub-unit and the head is called F_1 sub-unit.

Inner to these membranes there is present matrix which besides other substances has 2–10 copies of double stranded circular DNA, RNA and ribosomes of 70S type. Due to the presence of DNA and ribosomes, mitochondria are semi-autonomous in nature. Mitochondria are called **power plants or power houses or cellular furnaces,** because energy in the form of ATP is produced in them from metabolic fuels. This synthesis of ATP in mitochondria is called **oxidative phosphorylation** which is O_2 dependent and light independent. Mitochondria as a place of cellular respiration was first observed by **Hogeboom.**

Enzymes of Krebs' cycle or TCA cycle or citric acid cycle are present in the matrix of mitochondria (except **succinic dehydrogenase** which is found attached to inner mitochondrial membrane), whereas of electron transport system and oxidative phosphorylation in cristae or oxysomes.

○ 70% of the total enzymes present in a cell are present alone in mitochondria.

Chemically mitochondria possess proteins (65–75%), phospholipids (about 25%), DNA and RNA (small amount).

- Mitochondria provide a large number of intermediates for synthesis of different biochemicals like cytochromes, chlorophylls, alkaloids, steroids, etc. Further synthesis of many amino acids occurs in mitochondria.
- Mitochondrial inheritance, independent of nuclear inheritance is found in some cases. Petite character in yeast and **cytoplasmic male sterility** in maize are examples of mitochondrial inheritance.
- Mitochondria are believed to be **bacterial endosymbionts** of cells because:
  - (i) They have their own nucleic acids and ribosomes.
  - (ii) They replicate independently of the cell's division cycle, *i.e.*, do not arise *de novo*.
  - (iii) Their membranes resemble those of bacteria. Outer membrane of mitochondria contains proteins called **porins,** which are also found as part of the cell wall of certain bacterial cells (gram –ve bacteria). Further, both mitochondria and bacteria carry out energy conversions on the inner surface of their membranes.

2. PLASTIDS

The term plastid has been derived from the Greek word *Plastikas* : formed or moulded.

- E. Haeckel (1865) gave the term plastid. Plastids are largest cell-organelles. These are involved in the formation and storage of soluble and insoluble carbohydrates.
- Schimper divided plastids into three types on the basis of presence or absence of different pigments.
  - (I) **Chloroplasts** (*Chloro*– green + *plast*– living): These are **green plastids.**
  - (II) **Leucoplasts** (*Leukos*– white + *plast*– living): These are **colourless plastids** found in storage organs away from sunlight, *e.g.*, underground roots or stems.
  - (III) **Chromoplasts** (*Chroma* – colour + *plast* – living): These plastids are **variously coloured,** *e.g.*, flowers, beet root, etc.

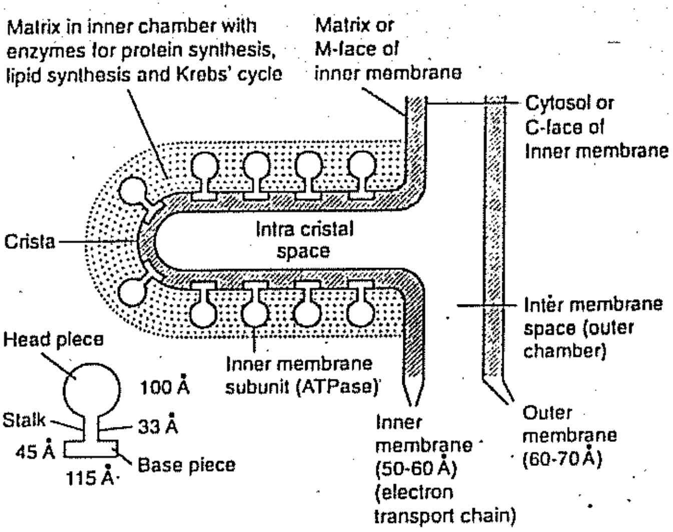

Matrix in inner chamber with enzymes for protein synthesis, lipid synthesis and Krebs' cycle
Matrix or M-face of inner membrane
Cytosol or C-face of Inner membrane
Crista
Intra cristal space
Inter membrane space (outer chamber)
Head piece
100 Å
Inner membrane subunit (ATPase)
Stalk
33 Å
45 Å
115 Å
Base piece
Inner membrane (50-60 Å) (electron transport chain)
Outer membrane (60-70 Å)

Fig. 4.6. Detailed structure of crista and oxysome

(I) Chloroplasts

Schimper (1883) gave the term chloroplast.

Morphology: Shape, size and number of chloroplasts vary from species to species. Shape may be:

(a) **Cup-shaped,** *e.g.*, *Chlorella, Chlamydomonas.*
(b) **Girdle-shaped,** *e.g.*, *Ulothrix.*
(c) **Star-shaped** or **stellate,** *e.g.*, *Zygnema.*
(d) **Spiral-shaped** or **scalariform,** *e.g.*, *Spirogyra.*
(e) **Reticulate** or **net-like,** *e.g.*, *Cladophora, Oedogonium.*
(f) **Discoid,** *e.g.*, *Vaucheria.*

In higher plants chloroplasts may be **ovoid, spheroid** or **disc-shaped** but mostly they are **lens-shaped.**

Size: Generally the size ranges between 4 µ–8 µ.

- Size ∝ ploidy level, *i.e.*, in polyploids, size is bigger.
- In shade plants (sciophytes), chloroplasts are larger. In light plants (heliophytes), chloroplasts are smaller.

Number: The number is also variable.

- Single chloroplast is found in cells of many algae, *e.g.*, *Chlamydomonas, Ulothrix, Chlorella.*
- Two chloroplasts in *Zygnema.*

- Two to fourteen in *Spirogyra*.
- In higher plants, 20–40 chloroplasts per cell have been reported.

Ultrastructure

Each chloroplast is bounded by two unit membranes separated by space called periplastidial space. Outer membrane contains integral proteins called porins, which make the membrane permeable to solutes of molecular weight as high as 10,000 daltons. The inner membrane is relatively impermeable and aid of different transporters is taken by substances passing through this membrane. Inner to membranes, matrix is present which is divided into two portions: (i) **Grana**, (ii) **Stroma.**

(i) **Grana:** Light reaction of photosynthesis occurs in this fraction. Grana fraction consists of membranous or lamellar system. This lamellar system is made up of **thylakoids** (term given by Menke, 1961), which are of two types:

(a) **Smaller thylakoids:** These are placed one above the other in the form of stacks of coins and form a **granum.** The number of grana per chloroplast is 40–60 and the number of thylakoids per granum is 10–100. On the inner face of thylakoid membrane, there are present minute granular structures called **quantasomes,** which are morphological expressions of photosynthetic units.

- **Park** and **Biggins** (1964) discovered quantasomes. Each quantasome is having 230 chlorophyll molecules.
  (The quantasome of bacteria is having only 50 chlorophyll molecules.)

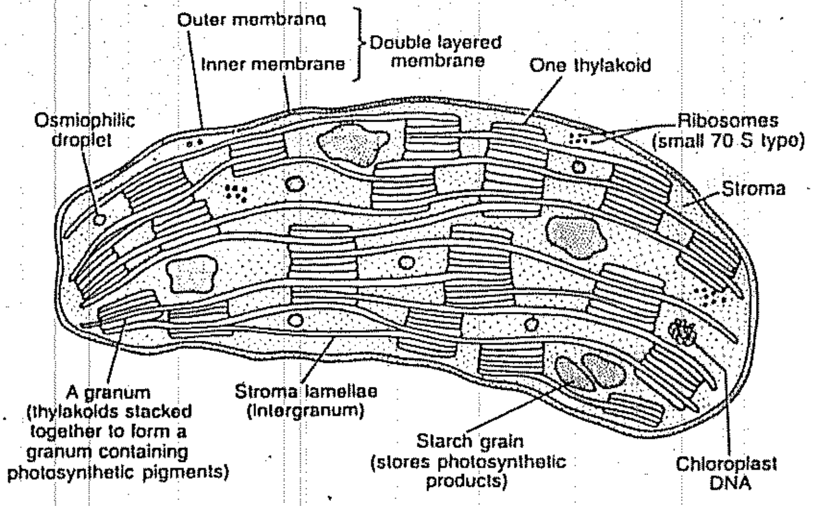
(b) **Larger thylakoids:** These are long membranous structures which are named as inter-granal lamellae or stroma lamellae or fret channels.

(ii) **Stroma:** Dark reaction of photosynthesis occurs in this fraction. The stroma is proteinaceous matrix. It has 20-60 copies of circular double stranded DNA. Each DNA copy is 40 μ in length which can code for 125 proteins.

- Chloroplast shows **semi-autonomous** nature due to presence of DNA, DNA polymerase, RNA polymerase enzymes and ribosomes (ribosomes of chloroplast are of 70S type).

Chemical composition of chloroplasts

Chloroplast is made up of proteins (40–50%), phospholipids (23–25%), chlorophylls (3–10%), carotenoids (1–2%), RNA (5%), DNA, enzymes, coenzymes, magnesium, iron, copper, zinc, manganese in traces.



Outer membrane
Inner membrane
Double layered membrane
One thylakoid
Osmiophilic droplet
Ribosomes (small 70 S type)
Stroma
A granum (thylakoids stacked together to form a granum containing photosynthetic pigments)
Stroma lamellae (Intergranum)
Starch grain (stores photosynthetic products)
Chloroplast DNA

Fig. 4.7. Ultrastructure of a chloroplast

Pigments of chloroplasts

Willstatter and **Stoll** observed the following pigments:

Chlorophyll-a ($C_{55}H_{72}O_5N_4Mg$)
Chlorophyll-b ($C_{55}H_{70}O_6N_4Mg$)
Chlorophyll-c ($C_{35}H_{32}O_5N_4Mg$)
Chlorophyll-d ($C_{54}H_{70}O_6N_4Mg$)
Chlorophyll-e
Carotenes → $C_{40}H_{56}$
Xanthophyll → $C_{40}H_{56}O_2$
} Carotenoids

Chlorophylls

The term chlorophyll was given by **Cavantou** (1818). A chlorophyll molecule has tetrapyrrolic or porphyrin **head** (15 Å × 15 Å) and phytol **tail** (20 Å long). Mg atom is present in the centre of porphyrin head. It is like a tennis-racket. If chlorophyll is burnt, only Mg is left.

(i) **Chlorophyll-a is a bluish green** micro-crystalline substance which is soluble in organic solvents. It is present in all photosynthesizing organisms except bacteria. In chloroplast, the Chl-a is 75%. In reflected light Chl-a shows blood red colour while in transmitted light, it shows blue-green colour.

(ii) **Chlorophyll-b is a yellowish green** micro-crystalline solid which is soluble in organic solvents. Chl-b is present in chlorophyceae, bryophytes, pteridophytes, gymnosperms and angiosperms while absent in cyanophyceae, phaeophyceae, bacillariophyceae, rhodophyceae and xanthophyceae. In chloroplast, the Chl-b is 25%. In transmitted light the Chl-b shows yellowish green colour while in reflected light it shows dull brown colour.

- In chlorophyll-b, the —CH_3 group on pyrrole ring II of porphyrin or tetrapyrrolic head is replaced by —CHO group.

(iii) **Chlorophyll-c** is present in phaeophyceae and bacillariophyceae.

(iv) **Chlorophyll-d** is present in rhodophyceae.

(v) **Chlorophyll-e** is present in xanthophyceae.

Carotenoids:

Carotenoids are hydrocarbons, soluble in organic solvents. These are of two types:

(i) **Carotenes:** The molecular formula is $C_{40}H_{56}$. These are **carrot coloured.**

(ii) **Xanthophylls:** The molecular formula is $C_{40}H_{56}O_2$. These are **yellowish orange** in colour.

- Molar ratio of carotenes and xanthophylls in young leaves is **2 : 1.**

Carotenoids are accessory pigments, first they protect the chlorophyll against photo-oxidation and then transfer light energy to chlorophylls.

Carotenoids are able to express themselves in mature leaves as chlorophyll begins to disintegrate.

- The main function of chloroplast is **photosynthesis**, in which radiant energy of sun is converted into chemical form of energy, which is utilized by all living organisms to perform their life activities. Further, chloroplasts help in maintaining balance of O_2 and CO_2 in the atmosphere.
- Chloroplasts are also believed to be **bacterial endosymbionts** of cells because:
  - (i) They have their own nucleic acids and ribosomes.
  - (ii) Their membrane resembles with that of bacteria (having proteins called **porins.**)
  - (iii) They reproduce or replicate independently of the cell's division cycle (*i.e.*, do not arise *de novo*).

(II) Leucoplasts

These are colourless found in storage organs away from sunlight, *e.g.*, underground stem or root. These are generally rod-shaped or circular. Leucoplasts are of three types:

(a) **Aleuroplasts or Proteinoplasts:** These store proteins, *e.g.*, in maize.

(b) **Elaioplasts or Oleosomes:** These store lipids or fats, *e.g.*, in endosperm cells of castor seeds.

(c) **Amyloplasts:** These store starch, *e.g.*, in potato tubers, wheat grains.

(III) Chromoplasts

These are variously coloured except green, *e.g.*, in flowers, in beet root, in some young leaves, ripened fruits as well as in algae and bacteria. These are of different types in algae and bacteria.

(a) **Rhodoplasts:** These are found in red algae (rhodophyceae). Here Chl-a is present along with Chl-d, R-phycoerythrin and R-phycocyanin (phycobilins); the red pigments are also present.

(b) **Phaeoplasts:** These plastids are found in brown algae (phaeophyceae). Fucoxanthin (brown pigment) is present along with Chl-a and Chl-c.

(c) **Chromatophores:** These are present in blue-green algae and bacteria. Chlorophyll-a, C-phycocyanin and C-phycoerythrin are present in chromatophores of blue-green algae while in chromatophores of photosynthetic bacteria, **bacteriochlorophyll** ($C_{55}H_{74}O_6N_4Mg$) or **chlorobium chlorophyll** is present.

These different types of plastids are interchangeable.

$$\begin{tikzcd}
\text{Leucoplast} \arrow[rr, shift left] & & \text{Chloroplast} \arrow[ll, shift left] \arrow[dl, shift left] \\
& \text{Chromoplast} \arrow[ul, shift left] \arrow[ur, shift left] &
\end{tikzcd}$$

e.g., **In tomato:**

Young ovary (colourless) ⟶ Leucoplasts

Young fruits (green) ⟶ Chloroplasts

Mature fruits (red) ⟶ Chromoplasts

In potato:

Leucoplast ⟶ Chloroplast

In carrot root:

Leucoplast ⟶ Chromoplast

- Plastid inheritance independent of nuclear inheritance has been observed in *Mirabilis jalapa* (4 o'clock plant).
- **Plastidome** (Dangeard, 1920): It is the sum total of plastids (carrying genetic information) in a cell.
- **Nitroplast:** The chloroplast with nitrogen fixing genes (nif genes) constitutes nitroplast.

3. ENDOPLASMIC RETICULUM

In the cytoplasm some closed or open, branched cavities are present which are bounded by membranes to form a network of membranous system called **endoplasmic reticulum.** ER forms 30–60% of endomembrane system of the cell. **K.R. Porter** (1948) first of all reported this net-like system under electron microscope. Endoplasmic reticulum is absent in prokaryotic cells, eggs and embryonic cells, while much developed in young meristematic cells.

Endoplasmic Reticulum

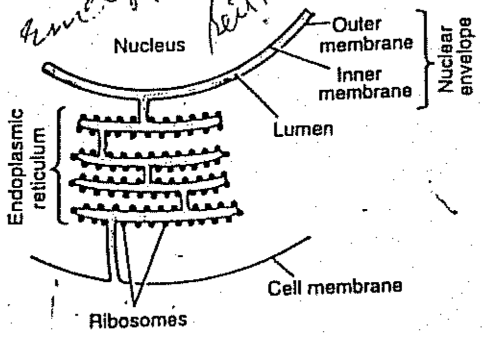


Fig. 4.8. Structure of endoplasmic reticulum

Ultrastructure

Endoplasmic reticulum is a hollow membranous system extending from nuclear envelope to cell membrane. It is composed of three types of structures:

(i) Sac-like flattened, unbranched structures called **cisternae.**

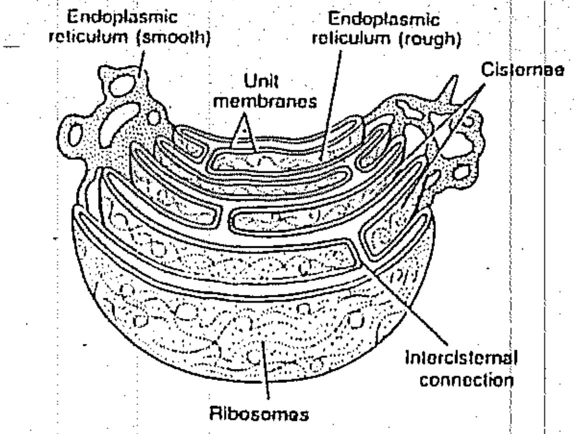

Endoplasmic reticulum (smooth)
Endoplasmic reticulum (rough)
Cisternae
Unit membranes
Intercisternal connection
Ribosomes

Fig. 4.9. 3-dimensional view of a part of E.R.

(ii) Small rounded structures, vesicles, having diameter of 25–500 mμ.

(iii) Branched tubular structures having a diameter of 50–100 mμ.

Depending upon the presence and absence of ribosomes, endoplasmic reticulum is of two types:

(a) **Smooth walled or agranular endoplasmic reticulum:** This type of endoplasmic reticulum is devoid of ribosomes. It is mainly present in cells which are involved in lipoproteins and glycogen synthesis. Smooth ER (SER) is generally peripheral in position and may be connected with plasma membrane. It is mainly made of vesicles and tubules.

(b) **Rough walled or granular endoplasmic reticulum:** In this type of endoplasmic reticulum, ribosomes are attached with the help of ribophorines I and II having molecular weight 65,000 daltons and 63,000 daltons respectively. These ribophorines are transmembrane glycoproteins. Larger unit of ribosomes (60S) is attached to endoplasmic reticulum. Rough endoplasmic reticulum is present in cells which are involved in protein synthesis. It is mostly present in the basophilic regions of the cytoplasm (ergastoplasm) which have plenty of ribosomes. In liver and pancreas, rough endoplasmic reticulum is present in abundance. Rough ER (RER) is generally internal in position and is connected with nuclear envelope. It is mostly made of cisternae and a few **tubules**. The RER membrane bears a fine pore in the area of attached ribosome so as to pass the synthesized protein or polypeptide into the lumen of ER for transport.

Functions of endoplasmic reticulum

(i) It provides mechanical support and acts as **endoskeleton or cytoskeleton** of cell.

(ii) Translocation of materials by diffusion.

(iii) Rough endoplasmic reticulum provides site for protein synthesis due to the presence of ribosomes on it.

(iv) It is related with lipoprotein, glycogen synthesis and storage (SER).

(v) A special type of endoplasmic reticulum, **the sarcoplasmic reticulum,** found in skeletal muscle cells releases Ca^{2+} which helps in muscle contraction. The Ca^{2+} plays an important role in the fusion of vesicles (phragmoplasts) in cell plate formation and also helps in movement of chromosomes.

(vi) Various cell organelles are kept in their position by ER.

(vii) Microbodies called **sphaerosomes** are formed by SER, while RER in association with Golgi complex gives rise to lysosomes.

(viii) Some of the specific functions of SER include **synthesis of steroid hormones** in endocrine cells of gonad and adrenal cortex, **detoxification** of a variety of organic compounds in liver and release of glucose from glucose-6-phosphate in liver cells by glucose-6-phosphatase enzyme in SER membrane.

(ix) Almost all the proteins produced on membrane bound ribosomes are converted into glycoproteins and this **glycosylation** occurs in rough ER (RER).

Chemical composition

Chemically endoplasmic reticulum is made up of **lipids** and **proteins**. In smooth endoplasmic reticulum, lipid contents are more than protein contents.

Origin

Origin of ER is from pre-existing ER or plasma membrane or nuclear envelope.

4. GOLGI APPARATUS OR GOLGI COMPLEX OR LIPOCHONDRION OR DICTYOSOMES

Camillo Golgi (1898), a zoologist, first of all observed Golgi bodies in the form of a network in nerve cells of barn owl. These bodies were initially known as **Dictyosomes** (Greek: *Dictyes*- net + *soma*- body). **C. Golgi** got the **Nobel Prize** for this work in 1906.

Golgi bodies are absent in prokaryotic cells and present in eukaryotic cells except in male gametes of bryophytes and pteridophytes, mamalian RBCs, sieve tubes of plants and in cells of fungi.

Ultrastructure

Golgi complex is made up of sac-like flattened structures or saccules or cisternae. The margins of cisternae are slightly curved, so each cisterna has a convex *cis*- or **forming** face facing nucleus or endoplasmic reticulum, whereas concave *trans*- or **maturing** face, facing plasma membrane. On the margins of cisternae, certain vesicles are present. The number of cisternae in a Golgi-apparatus varies from 3–20. (In liver cells the number is upto 50).

The Golgi bodies are interconnected with the tubules which arise from the periphery of cisternae (**Mollenhaver and Moore**, 1967).

- In plant cells, a single Golgi stack is generally called a dictyosome.

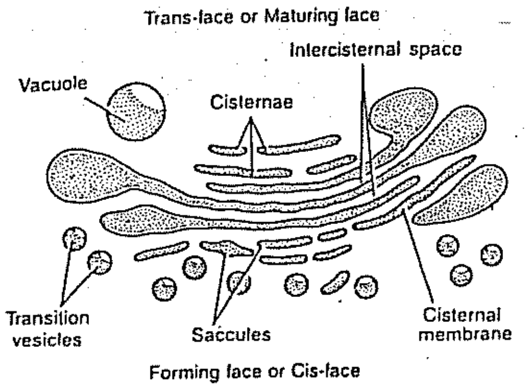


Fig. 4.10. Structure of Golgi apparatus

Functions

(i) The main function of Golgi apparatus is of packaging and storage of materials.

(ii) During cytokinesis, small vesicles (phragmoplasts) are provided by Golgi complex which help in the cell plate formation.

(iii) Cell wall materials especially hemicellulose is secreted by Golgi complex which helps in cell wall formation.

(iv) Secretion of different substances like gum, mucilage and hormones of endocrine glands in animals.

(v) Golgi bodies form acrosome during spermatogenesis.

(vi) These bodies are helpful in transportation of different substances and transformation of membranes of one type into another.

(vii) Some special carbohydrates, like **sialic acid** (N-acetylneuraminic acid, found in plasma membrane) and galactose are synthesized inside Golgi complex.

(viii) Golgi complex is primarily a **processing plant**. Newly synthesized proteins by RER are modified in specific ways in Golgi complex, *e.g.*, their amino acids may be modified or their length may be trimmed by proteolytic enzymes or their carbohydrate content may be modified by stepwise enzymatic reactions.

(ix) Proteins and lipids are **glycosylated** to form glycoproteins and glycolipids with the help of a characteristic enzyme called glycosyltransferase.

5. RIBOSOMES

Ribosomes are minute cellular, non-membranous particles having an average diameter of 23 nm (230 Å). In plant cells ribosomes were first of all observed by **Robinson and Brown** (1953) in bean roots.

In animal cells these were observed by **Palade** (1955), hence are called **Palade particles**. Ribosomes form a part of fraction microsome, a term given by **A. Claude** (made of broken ER, ribosomes and Golgi bodies).

Ribosomes are made up of r-RNA (40–60%) and proteins and due to presence of ribonucleic acid, these particles are called ribosomes.

These are also known as RNP particles (Ribonucleoprotein particles).

Ribosomes are found in both prokaryotic and eukaryotic cells. The number ranges upto 5,00,000 per cell. In prokaryotic cells, the ribosomes are found in free state while in eukaryotic cells they may be free or found associated with ER by their larger subunits (with the help of ribophorins). Ribosomes are also found in mitochondria and plastids (organeller ribosomes).

Ultrastructure

- Ribosomes are very small organelles having a diameter of 150 Å–250 Å. Each **ribosome** is made up of two subunits, a smaller subunit and another larger subunit. Depending upon the sedimentation coefficient, ribosomes are of two types:

(i) 70S Ribosome (Larger subunit 50S + smaller subunit 30S): These ribosomes are found in prokaryotes, chloroplasts and mitochondria. These are smaller in size (having size 29 nm × 21 nm and molecular weight 2.7×10^6 daltons).

(ii) 80S Ribosome (Larger subunit 60S + smaller subunit 40S): These ribosomes are found in eukaryotic cells (having size 30–34 nm × 20–24 nm and molecular weight 4.0×10^6 daltons).

- The two subunits of ribosomes are associated with the help of Mg^{2+} ions (at 0.001 M concentration).
- If the Mg^{2+} ions concentration is less in cytoplasm, the two units of ribosome separate.
- When the Mg^{2+} ions concentration is increased ten times, two ribosomes unite and form a **Dimer** (120S).
- During protein synthesis, 4–5 ribosomes are present in group on m-RNA, *i.e.*, **polyribosome** or **polysome**. The smaller unit of ribosome is attached to m-RNA.

James A. Lake (1981) represented the fine structure of ribosome, according to which the smaller subunit consists of three parts, *i.e.*, a head, a base and a **platform** (which is separated from head with the help of a cleft).

In the same way the larger subunit consists of a **ridge**, a **central protuberance** and a **stalk**.

Chemical composition

Ribosomes are chemically composed of r-RNA and **proteins**.

- Lipids are altogether absent in ribosomes. Ribosomes are strongly negative binding cations and basic dyes.
- In ribosomes, 60% RNA is double stranded or helical.
- The subunits of both types of ribosomes are having smaller subunits or components.
- 50S subunit of prokaryotic ribosomes (70S) is made of core particles of 40S and split proteins (SP50). Core particles are further having RNA and core particles. Similar is the case in eukaryotic (80S) ribosome.
- Out of the total RNA contents of a cell, 70–75% is present in ribosomes.

Chemically in 70S ribosomes, r-RNA and proteins are 60–64% and 36–37% respectively whereas this percentage in 80S ribosomes is 36–37% and 56–60% respectively.

Function

Ribosomes are involved in protein synthesis. 'Free' ribosomes synthesize structural proteins (peripheral or extrinsic proteins of inner surface of plasma membrane), proteins normally found in microbodies, chloroplast and mitochondria and proteins destined to remain in the cytosol such as enzymes of glycolysis or proteins of cytoskeleton, *i.e.*, free ribosomes synthesize proteins which are used inside the cell. On the other hand, 'ribosomes attached on ER' synthesize proteins for transport (*i.e.*, used outside the cell), integral or intrinsic proteins of membrane and proteins of certain organelles like Golgi complex, lysosomes and plant vacuoles.

- Gunter Blobel and David Sabatini of Rockfeller University proposed signal hypothesis in 1971. According to this hypothesis the synthesis of a protein on a membrane bound or a free ribosome is determined by the information contained in the N-terminal portion of polypeptide (first part to emerge from ribosome during protein synthesis). Gunter Blobel has been awarded the **Nobel Prize** (1999) for this protein signalling.

Origin

Nucleolus is mainly involved in formation of ribosomes

6. MICROBODIES

Microbodies are very small spherical bodies bounded by a **single unit membrane**. These have been discovered with the help of electron microscope in some plants, fungi and protozoans. These are as follows:

(A) Lysosomes,
(B) Peroxisomes,
(C) Sphaerosomes,
(D) Glyoxysomes and
(E) Lomasomes. Lomasomes

(A) Lysosomes

Lysosomes are frequently present in animal cells but these are also reported in plant cells.

- **C. de Duve** (1955) observed rounded dense bodies in liver cells. These bodies were initially known as **'pericanalicular dense bodies'** but later on he renamed these bodies as **lysosomes** (*Lyso*-digestive + *soma*-body).
- **P. Matile** (1964) reported lysosomes in plant cells, *i.e.*, red mould or *Neurospora* (Fungus).
- Lysosomes are **0.23–0.50 μ** in size and are bounded by **single unit membrane**.
- They contain large number of **hydrolytic enzymes** or **hydrolases**, namely acid phosphatase, acid ribonuclease, acid deoxyribonuclease, cathepsins, sulphatases, etc. All these enzymes show maximum activity at **pH 5.0** (in acidic medium).
- **ATP** driven **H-pump** is present in **lysosome** membrane which provides protons and hence maintains acidity.
- Lysosomes are sometimes termed as **'Suicide bags'** because they not only hydrolyse the external particles but also destroy nearby defected cytoplasm.

Types of lysosomes

Lysosomes show **polymorphism** or presence of different morphological forms. They pass through different stages in the same cell. Lysosomes are divided into four types on the basis of their function and morphology:

(a) **Primary lysosomes** or **Protolysosomes** or **Starch granules:** Lysosomes having their enzymes only are primary lysosomes.

(b) **Secondary lysosomes or Heterophagosomes or Digestive vacuoles:** The lysosomes having enzymes as well as the digested material or the material to be digested, are secondary lysosomes.

(c) **Residual bodies:** These are secondary lysosomes having incompletely digested materials.

(d) **Autophagic vacuoles** or **Autophagosomes** or **Cytolysosomes:** The lysosomes containing intracellular structures like mitochondria or endoplasmic reticulum for digestion, are autophagosomes.

Functions

The main function of lysosomes is of digestion as:

(i) **Digestion of intracellular substances:** Lysosomes digest the substances (proteins, fats, etc.) present inside the cell. This is done during starvation and thus nourishment is provided by lysosomes.

(ii) **Digestion of external particles:** The external particles are taken inside the cell through the process of phagocytosis. The cell wall forms an **invagination** in which the molecule is **enclosed** and a vesicle or **phagosome** is formed. This **phagosome** attaches with the **lysosome**, the enzymes of which digest it. This is called **intracellular digestion**, which is the main function of lysosomes.

(iii) **Cellular digestion:** The enzymes from the lysosome of a dead cell are released which **digest** the cell organelles (autophagy). Further hydrolases released by lysosomes of damaged or ageing cells digest them (Autolysis). So the lysosomes are also called 'suicidal bags'.

(iv) **Extracellular digestion:** The enzymes of lysosomes are released outside the cell, ***e.g.*, the protective coat of ovum** is dissolved by the **enzymes** liberated by the **lysosome of sperm.**

(v) The process of **mitosis** is **initiated** by the lysosomes.

Origin

Golgi bodies form vesicles which are filled with the enzymes synthesized on ribosomes and these enzymes are transported by the involvement of endoplasmic reticulum and thus lysosomes are formed.

(B) Peroxisomes

Under electron microscope along with lysosomes another type of spherical bodies were reported, which were known as peroxisomes, which are present in both plants and animals.

- Tolbert (1969) discovered them from liver cells. These peroxisomes = hy… peroxide

organelles were named peroxisomes because these are the sites of formation of hydrogen peroxide (H_2O_2), formed by a number of enzymes including urate oxidase, glycolate oxidase and amino acid oxidases (H_2O_2 is a highly reactive and toxic oxidizing agent).

- Peroxisomes are found only in C_3 plants where a wasteful phenomenon of photorespiration occurs. These are also reported in animal cells, *i.e.*, liver and kidney cells.
- Peroxisomes are the smallest membrane bound cell organelles having a diameter of 0.1 μ.

The number of peroxisomes varies from 70–100 per cell. It consists of a granular matrix in which twisted strands are present in the centre. The peroxisome contains several enzymes such as amino transferase, glycolate oxidase, glyoxylate reductase, peroxidase and catalase, etc. (Catalase destroys H_2O_2 produced during the conversion of glycolate to glyoxylate. Catalase enzyme is present in high concentration in these organelles).

Function

. Mainly the peroxisomes participate in photorespiration in C_3 plants and are associated with lipid metabolism in animal cells. These are also associated with oxidation of amino acid and uric acid. Peroxisomes are highly versatile molecular factories having enzymes that participate in oxidation of very long chain fatty acids (more than 18-carbons), synthesis of cholesterol and bile acids in liver and synthesis of plasmalogens (phospholipids in brain tissue). **Luciferase** enzyme, generating light in fire flies, is also present in peroxisomes.

(C) Sphaerosomes

Previously, it was considered that sphaerosome is the lysosome of the plant cell as most of the enzymes present in sphaerosomes are identical to those of lysosomes. But now it has been established that some additional enzymes are also present in sphaerosomes. These were discovered by **Hanstein (1880)**.

Sphaerosomes are small spherical vesicles, having a diameter of 0.2–0.8 μ, bounded by a single unit membrane. These are formed from smooth ER.

They contain many enzymes, *i.e.*, ribonucleases, esterases, phosphatases, proteases, hydrolases, etc.

Function

Sphaerosomes are associated with the synthesis and storage of fats and oils.

(D) Glyoxysomes

Glyoxysomes were first discovered by **Beevers in 1961** from castor-bean endosperm. These are small, spherical vesicles enclosed by a single unit membrane. These are most prominent in plant seedlings.

Glyoxysomes are generally found in cells of yeast, *Neurospora* and in germinating fatty seeds where fat is being converted into carbohydrates, *i.e.*, glyoxylate cycle (gluconeogenesis).

Various enzymes of glyoxylate cycle are present in glyoxysomes, namely—malate synthetase, aconitase, isocitric lyase, citrate synthetase, malate dehydrogenase, glycolate oxidase and catalase.

Fats → carbohydrates.
Gluconeogenesis

(E) Lomasomes

Lomasomes are small vesicular bodies present between cell wall and plasma membrane in plant cells.

Function

Lomasomes are associated with the synthesis of cell wall material.

7. CENTROSOME

Centrosome is present in all animal cells, but in plants it is present in lower plants only, *i.e.*, fungi, bryophytes, ferns, gymnosperms and algae (absent in red algae).

T. Boweri (1888) coined the term centrosome to signify a region of clear cytoplasm lying near the interphase nucleus. Each centrosome consists of **two sets of centrioles.** Two centrioles of each set are known as **diplosomes**, which are located at right angles to each other. Each centriole is made up of nine sets of triplets arranged parallel to each other, forming a cylindrical structure, 300–500 nm in length and 150–180 nm in diameter (9 + 0 arrangement).

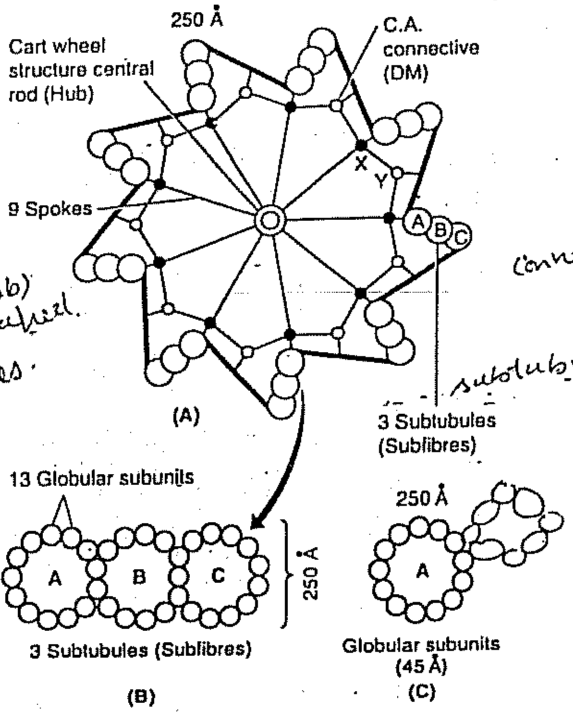


Fig. 4.11. (A) Transverse section of centriole, (B) Three subtubules, (C) A subtubule

Sat (Hub) cart wheel.
9 spokes.

conne

subtubu

Each triplet makes an angle of 40° with the radius of cylinder. In a triplet there are three secondary fibres or microtubules, each having a diameter of 200 Å. The first tubule of a triplet is connected with the third tubule of the next triplet.

The triplets are not enclosed by a membrane but seem to be embedded in the material. The arrangement of the microtubules looks like a wheel. Around the centrioles, there is a clear area, which is called **centrosphere**, from which the rays radiate in all directions. These rays are called aster.

Centrioles along with centrosphere comprise the centrosome. During mitosis centrosome divides into two; one of them moves to the opposite pole, while another remains at its own position and thus helps in division of cell.

Function

Centrosome participates in the formation of spindle fibres, basal bodies, cilia, etc. Basal bodies are formed from centrioles and both have a common structure (9 + 0 arrangement).

Origin

Centrosome originates from centriole which is a semi-autonomous body. It gives rise to a daughter centriole which matures during late prophase.

8. CILIA AND FLAGELLA

Cilia and flagella are contractile, cytoplasmic projections extending outside the cell through pores of cell wall. These are formed from the basal bodies inside the cytoplasm.

Cilia and flagella are sensory organs which help in cell movement and perform **mechanical function.**

Ultrastructure

Both cilia and flagella have almost similar internal structure. These are bounded by a unit membrane (95 Å) which encloses a matrix having **eleven microtubules or fibrils.**

Out of these **eleven fibrils, nine** are situated at the **periphery** (each having a diameter of 360 Å) and **two** are present **in centre** (having a diameter of 250 Å). Thus a **9 + 2 pattern** is observed.

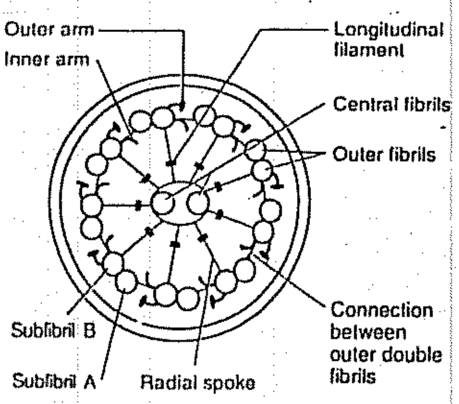


Fig. 4.12. T.S. of flagellum

- The peripheral fibrils are made up of **tubulin protein** (mol. wt. 1.20.000 daltons). Each peripheral fibril is composed of two subfibrils, *i.e.*, subfibril A, which is larger and incomplete and subfibril B, which is smaller and complete having projections (made up of dyncin protein).
- The central fibrils are made up of **dyncin protein** (mol. wt. 6,00,000 daltons) and ATPase enzyme. Each central fibril has a single subfibril.
- It is seen that separated cilia or flagella show movement if provided with ATP. Movement of cilia and flagella is generated by microtubules.
- Depending upon the presence or absence of lateral hair, flagella are of two types, *i.e.*, **tinsel** having small hair like outgrowths and **whiplash** in which these hair are absent.

Although cilia and flagella are morphologically similar to some extent but there are some differences:

	Flagella	Cilia
Number	1 or 2	Many (in thousands)
Length	150 μ	5–10 μ
Position	Generally at ends	All over the surface
Movement	Independent or undulatory movement	Sweeping or pendulatory

9. CYTOSKELETON

Cytoskeleton is associated with cell motility. It is made up of three elements within the cell:

(i) Microtubules,
(ii) Microfilaments and
(iii) Intermediate filaments.

cytoskeleton is made up of

(i) Microtubules

Microtubules were discovered by **De Robertis** and **Franchi** (1953) in the nerve fibres while in plant cells these were observed by **Ledbetter** and **Porter** (1963). Microtubules are found in many plant and animal cells, *i.e.*, in centrioles, basal bodies, flagella, cilia, spindle fibres, etc.

Microtubules are tube-like, unbranched cylindrical structures having a diameter of 200–300 Å (20–30 nm). T.S. of microtubules shows array of 13 rows of subunits, *i.e.*, protofilaments having a diameter of 5–7 nm. Chemically these filaments are made of **tubulin protein** (mol. wt. 1,10,000–1,20,000 daltons), which is a dimeric protein made of α-tubulin and β-tubulin (each having mol. wt. 60,000 daltons).

(ii) Microfilaments

These are long fibres of variable length (5–7 nm) forming a web in ectoplasm. Microfilaments are made of protein **actin**. These filaments help in cell movement and in formation of cell furrow and cell plate.

(iii) Intermediate filaments

These filaments are unbranched, made up of structural proteins, *i.e.*, kerotin, vimentin and desmin. Intermediate filaments are about 10 nm in thickness and are larger than microfilaments. These filaments help the nucleus in maintaining its position in the cell and often interconnect the nucleus envelope with the cell membrane.

NUCLEUS

Robert Brown (1833) discovered a dense, spherical body in the cells of an 'orchid' and named it as 'Nucleus'. The synonym term of nucleus is Karyon and the branch dealing with its study

Flagella two types (1) [illegible] Nine + two tubulin protein Dynein protein 6 - 8 VI

is known as **'Karyology'**. Nuclei arise from pre-existing nuclei was first suggested by Strasburger (1873).

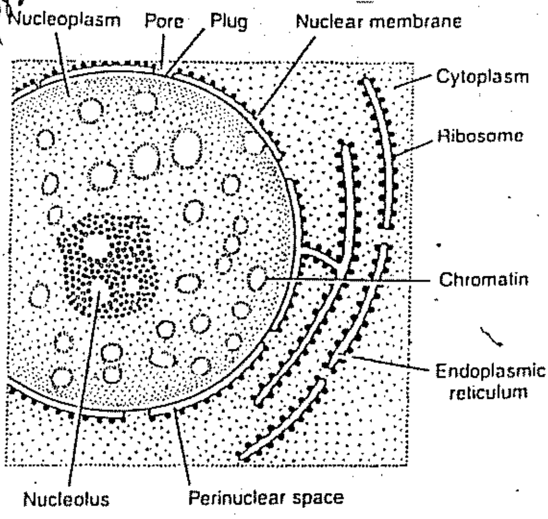


Fig. 4.13. Structure of nucleus

- **Nucleus is the 'controlling centre of cell'** as it contains chromosomes and genes. **J. Hammerling** (1934), a German biologist, proved this by performing grafting experiments on two species of unicellular green alga *Acetabularia*, *i.e.*, *A. mediterranea* and *A. crenulata*. This alga is having rhizoidal portion, stalk and cap. Nucleus is present in rhizoid. The cap of *Acetabularia crenulata* has loose rays while that of *Acetabularia mediterranea* is umbrella-like. It was observed that if the stalk of one species is grafted on the rhizoid of another species, then the cap formed is similar to that species to which the rhizoid belongs. It proves that the shape of the cap is determined by the nucleus which is present in rhizoid.

Number

Usually there is a **single nucleus** per cell, *i.e.*; **mononucleate** condition. There may be **binucleate** (*e.g.*, in *Paramoecium*) or **polynucleate** condition also.

- Polynucleate condition may be because of fusion of a number of cells, *i.e.*, **syncytium** (coconut endosperm) or by free nuclear divisions without cytokinesis, *i.e.*, **coenocyte** which is commonly found in plants. In some cells, as sieve tubes of plants and mammalian erythrocytes, nucleus is present during early stage but degenerates at maturity. Due to this reason these cells have a short life span.
- In prokaryotes, *i.e.*, bacteria, blue-green algae (cyanobacteria), mycoplasma, etc., definite nucleus is absent while incipient nucleus or prokaryon or nucleoid is present.

Shape

Shape of the nucleus varies depending upon the type of cell. It may be spherical, oval, elongated or flattened. The branched nuclei are sometimes present in glandular cells. In some cells the nucleus is irregular, *i.e.*, in some leukocytes.

Size

The size of the nucleus is variable, *i.e.*, 5–30 μ. In metabolically active cells, size of the nucleus is larger than metabolically inactive cells.

Chemical composition

Chemically the nucleus consists of proteins (about 70%), phospholipids (about 5%), DNA (about 10%), RNA (about 2–3%).

Structure

Nucleus is made up of the following four parts:

(1) Nuclear membrane or nuclear envelope or karyotheca,
(2) Nuclear sap or nucleoplasm or karyolymph,
(3) Nucleolus and
(4) Chromatin threads or chromosomes.

(1) Nuclear membrane

The nucleus is separated from cytoplasm by nuclear membrane. This membrane enclosing nucleoplasm is made up of two unit membranes (each 75 Å thick). The space between these two membranes is known as **perinuclear space**, which is variable (15 nm or more). The outer unit membrane is continuous with the membrane of endoplasmic reticulum and has ribosomes studded on it.

The continuity of nuclear envelope is broken by minute pores called **nuclear pores** having a diameter of 10 nm–100 nm. Large particles like ribosomes (20–25 nm) can pass through these pores. Nuclear pores are often plugged with distinct fibrous material called **annulus** (only in animal cells) to avoid the free nucleo-cytoplasmic exchange. Difference in pH of cytoplasm and nucleus is also a point against the free exchange.

- Below the nuclear envelope, there is present a filamentous network of protein called **nuclear lamina**. Its function is to attach chromosomes to nuclear envelope and to help in the growth of nuclear envelope.

(2) Nuclear sap or Nucleoplasm

Inside the nuclear envelope, there is present a granular, transparent substance known as nucleoplasm or nuclear sap or karyolymph. It is chemically made of nucleic acids, enzymes, lipids, minerals and proteins (histone and non-histone).

Nucleoplasm is the site of enzyme activities and the synthesis of DNA, RNA and ribosomal subunits takes place here.

Nucleolus and chromatin material are present in nucleoplasm.

(3) Nucleolus

Nucleolus is a dense, spherical, colloidal body which remains attached with nucleolar organizing chromosomes.

- It was discovered by **Fontana** (1781) and termed as 'nucleolus' by **Bowman** (1840).
  Sometimes more than one nucleoli are observed in the same nucleus (*e.g.*, in the nucleus of onion).

Nucleolus is made up of four parts:

(i) **Granular part** is made up of ribonucleoprotein granules (r-RNA and proteins are present in ratio of 2 : 1) having a diameter of 150 Å to 200 Å. These granules are also called nucleolar ribosomes.

(ii) **Fibrillar part** is made up of fibrils of ribonucleoproteins called nucleonema having a diameter of 50 Å.

(iii) **Amorphous matrix or Pars amorpha:** This is a homogeneous substance having protein granules and fibrils.

(iv) **Chromatin:** It is feulgen positive and is of two types:
  (a) **Perinucleolar chromatin** which covers the nucleolus and
  (b) **Intranucleolar chromatin** is present inside the nucleolus.

Function: The main function of nucleolus is the synthesis of ribosomal RNA (r-RNA) and it is called store house of RNA. Besides this it plays an important role in cell division also.

(4) Chromatin threads or Chromosomes

During interphase, chromatin threads are present in the form of a network called chromatin reticulum. At the time of cell division, these thread-like structures of chromatin reticulum become visible as independent structures.

- **E. Strasburger** (1875) discovered these distinct structures during cell division.
- **Waldeyer** (1888) gave the term chromosomes (*Chroma*-colour + *soma*-body) to them because they get stained with basic dyes like basic fuchsine and acetocarmine.
- In all eukaryotes, the nucleus contains definite number of chromosomes having definite size and shape.

Number: Chromosome number is variable.

- Least chromosome number in plants is $2n = 4$ ($n = 2$) in *Haplopappus gracilis* (Compositae) and highest is $2n = 1262$ in *Ophioglossum* (a pteridophyte).
- In a protozoan, radiolarian, *Aulacantha*, the diploid number is $2n = 1600$.
- 'n' represents the gametic or haploid chromosome number.
- '$2n$' is the diploid or somatic number.
- 'x' is the basic chromosome number or primitive ancestral number in polyploids, *e.g.*, in wheat (hexaploid), $2n = 6x = 42$, where $n = 21$ (gametic or haploid number) and $x = 7$ (basic chromosome number).

Size

- The size of chromosome is variable (0.25–30 μ) and can be measured at metaphase during mitosis.
- The smallest chromosome is of 0.25 μ observed in fungi and birds, while the largest in some plants like *Trillium* is of 30 μ.

Shape

- Shape of chromosome can be determined at anaphase.
- Depending upon the position of centromere or kinetochore (a point where spindle fibres attach during cell-division and angular deviation or bending occurs), the shape of the chromosome may be:
  (a) **Telocentric:** In these chromosomes, the centromere is present at one end. The shape of chromosome is rod-like.
  (b) **Acrocentric:** Centromere is present at terminal position (*i.e.*, slightly away from end), because of which one chromosome has a long and another a very short arm.
  (c) **Sub-metacentric:** Centromere is located near the centre, so the chromosome has one long and another slightly shorter arm. The chromosome may be 'L' or 'J'-shaped.
  (d) **Metacentric:** Centromere is present in centre of the chromosome, hence both the arms are equal. These are 'V'-shaped chromosomes.
  (e) **Acentric:** When centromere is absent.

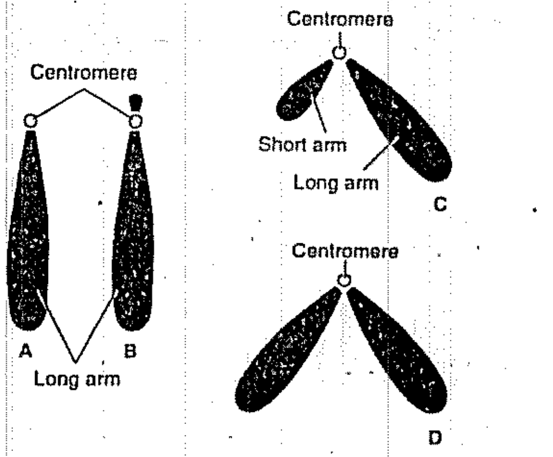


Fig. 4.14. Shapes of chromosomes: A. Telocentric, B. Acrocentric, C. Sub-metacentric, D. Metacentric

Depending upon sex and other body characters, the chromosomes in eukaryotes are of two types:

(i) **Autosomes:** These are more in number and have nothing to do with sex, but determine other body characters.

(ii) **Sex chromosomes or Heterosomes or Odd chromosomes or Idiosomes:** These chromosomes are concerned with sex. These are of 'X' and 'Y' type. 'X' chromosome is partly euchromatic and partly heterochromatic whereas 'Y' chromosome is heterochromatic.

Structure or Morphology

Structure of chromosome is clearly visible at metaphase.

- Each chromosome consists of two coiled filaments throughout its length, called **chromonemata by Vejdovsky.** Chromonemata have bead-like structures called **chromomeres,** which are thought to be the gene-bearing portions of chromosomes.

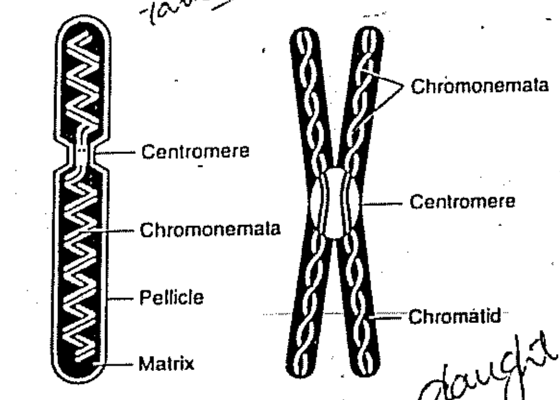
sine aci...

5 types of basic Histone pro...

H1, H2A, H2B, H3, H4

- Chromatid is a half chromosome or daughter chromosome. The two chromatids are connected at the centromere or primary constriction.
- The chromonemata are embedded in the non-genetic substance known as **matrix** which is bounded by a sheath called **pellicle**. Matrix and pellicle both are achromatic and present only at metaphase when nucleolus disappears.
- 4- Besides primary constriction (centromere), in some chromosomes, there is present secondary constriction also and due to this a small portion is pinched off from chromosome body. This portion is known as **satellite** or **trabant**. The chromosomes having satellite or trabant are called **SAT-chromosomes** (SAT: 'Sine Acid Thymonucleinico', having thymonucleic acid).
- Sometimes two satellites are present in a chromosome: these chromosomes are called **Tandem SAT-chromosomes**.
- SAT-chromosomes are used as **marker chromosomes**.
- The ends of the chromosomes are called **telomeres** (which do not unite with any other structure).

-tandem



(A) Structure of a chromosome

(B) A mitotic metaphase chromosome

daughter chromosome

Fig. 4.15. Structure of (A) Chromosome, (B) Metaphase chromosome with chromatids

Heterochromatin and Euchromatin

These terms were given by **Emil Heitz** (1928). It was observed that when chromosomes are stained with basic dyes like acetocarmine or feulgen (basic fuchsine), then two types of regions are distinguished:

(a) **Heterochromatic region:** This region gets dark stain during interphase and lighter during cell division. This region is generally present towards the end of chromosome and near primary constriction or centromere. This is a **genetically inactive** region having less amount of DNA.

(b) **Euchromatin region:** This region gets light stain during interphase and dark during cell division. This portion is **genetically active** and **rich** in DNA. Transcription occurs here.

i. formation of m-RNA

ii. [illegible]

Chemical composition

Chromosomes are **nucleoproteins** in nature. Major chemical constituents are:

(1) DNA: About 40%
(2) RNA: 1–10%
(3) Histones or basic proteins: 40–50%
(4) Non-histones: About 10%
(5) Small amount of Ca, Mg, etc., *i.e.*, in traces.

Generally, proteins are more than nucleic acids. DNA and histones are associated in the form of **nucleoprotein complex**. The proportions of different components vary from organism to organism.

(1) **DNA:** It is the most important component and has an important role in controlling heredity. DNA content varies in chromosomes of different organisms. In general, eukaryotes have 10–100 times DNA as compared to bacteria (prokaryote) in genomes.

4 ○ The unit of measurement of DNA is **picogram** (10^{-12} g), which is the weight of 31 cm of double stranded DNA. A diploid cell of human being is having 5–6 picogram of DNA (174 cm) and the total amount of DNA in a human being is estimated to be about 100 g having a length of 2.5×10^{10} km.

(2) **RNA:** It forms maximum 10% of chromosome.

(3) **Histones or Basic proteins:** These are rich in basic amino acids. DNA and histones are almost equal and are associated to form nucleoprotein complex.

- **Histones are of five types:**

H_1	Lysine rich
H_2A H_2B	Slightly lysine rich
H_3 H_4	Arginine rich

Histones isolated from different organisms show similarity. These perform regulatory function, *i.e.*, responsible for gene activities.

(4) **Non-histones:** These show great variability and also perform regulatory role.

Ultrastructure

Chromosomes are made of very fine fibrils 2 nm–4 nm in thickness. As the diameter of DNA molecule is also 2 nm (20 Å), so it is considered that a single fibril is a DNA molecule. It is also seen that chromosome is about a hundred times thicker than DNA whereas the length of DNA in chromosome is several hundred times that of the length of chromosome. So it is considered that long DNA molecule is present in folded manner which forms a famous model of chromosome structure called **'Folded Fibre Model'**, given by **E.J. DuPraw** (1965).

The most accepted model of chromosome or chromatin structure is the **'nucleosome model'**, proposed by **Kornberg** and **Thomas** (1974).

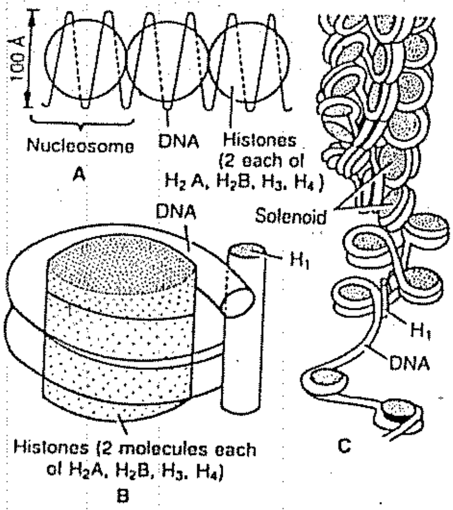

100 Å
Nucleosome
DNA
Histones (2 each of H_2A, H_2B, H_3, H_4)
A
DNA
Solenoid
H_1
H_1
DNA
Histones (2 molecules each of H_2A, H_2B, H_3, H_4)
B
C

Fig. 4.16. (A) Nucleosome units, (B) Nucleosome model, (C) Solenoid model

- Nucleosome, *i.e.*, subunit of chromatin is an octamer of histones (2 molecules each of H_2A, H_2B, H_3 and H_4) with DNA of 200 base pairs, *i.e.*, nucleosome is made of core of eight molecules of histones wrapped by double helical DNA with 1¾ turns making a repeating unit. Further, this unit is having a single molecule of H_1 histone at the ends.
- The name nucleosome was given by **P. Outdet** *et al.* (1975) for these repeating units of chromatin which are present as beads on string.
- The diameter of nucleosome is **12.5 nm**.
- Nucleosomes are also called 'core particles' or 'Nu-bodies'.
- The adjacent nucleosomes are joined by internucleosomal DNA or **linker DNA** and hence can be separated from chromosomes by treating chromatin with nuclease enzyme (which digests linker DNA).
- According to **A. Klug** (Nobel Prize winner, 1982), this chain of nucleosomes is **further folded or coiled** to form a **'solenoid'** (having six nucleosomes per turn).

Functions of chromosomes

Chromosomes are responsible for carrying the genetic information from one generation to another.

Special types of chromosomes or Giant chromosomes

In some organisms, the chromosomes assume special structures in some specific tissues, *e.g.*:

1. **Lampbrush chromosomes:** These are present in primary oocyte nuclei of vertebrates as well as invertebrates. These are also present in spermatocyte nuclei of fruitfly (*Drosophila*). These chromosomes attain a length of **800–1000 μ**; the maximum length of these chromosomes has been observed in urodele amphibians, *i.e.*, 1 mm (1000 μ).

These chromosomes are having a main axis made of DNA on which are present chromomeres and from each chromomere, 1–9 loops arise in pairs. The loop axis is again made of DNA which is surrounded by a matrix on both sides made of RNA and proteins. Due to pairs of loops, these chromosomes appear like lampbrush and hence called lampbrush chromosomes.

- These chromosomes form a large number of nucleoli but their significance is unknown.

2. **Salivary gland chromosomes or Polytene chromosomes:** In salivary gland cells of insects of order Diptera (dipteran insects), some special or giant chromosomes were reported by **E.G. Balbiani** (1881). It is due to the presence of these giant chromosomes that maximum cytological studies have been made in *Drosophila*.

- The size of these chromosomes increases upto 200 times or more than normal and in *Drosophila*, salivary gland chromosomes upto **2000 μ** (2 mm) have been observed. The name polytene chromosomes has been given to them as there occurs polyteny, *i.e.*, number of chromonemata or fibrils increases upto 2000 or more per chromosome. A characteristic feature of these chromosomes is that somatic pairing occurs in them and hence their number appears half of normal somatic cells.
- These chromosomes show distinct **dark** and **light bands**, *i.e.*, chromatic (dark) and achromatic (light) regions. Euchromatin is present in dark bands and heterochromatin is present in light bands. These bands help in mapping of chromosomes in cytogenetic studies.
- These chromosomes form puffs or loops (in region of dark bands), which are called **Balbiani puffs** or **Balbiani rings** where synthesis of m-RNA occurs.

B-Chromosomes

These are a type of supernumerary chromosomes, that may or may not be present in an organism as extra chromosomes over and above standard chromosome complement (Chromosomes of standard complement are called **A-Chromosomes**). The origin and function of these chromosomes are unknown.

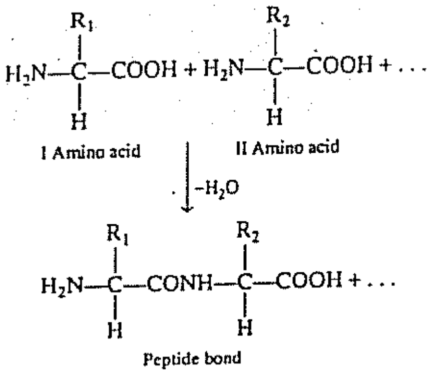
These B-Chromosomes show following characteristics:

(i) These are not found in all individuals of a species and in all cells of an individual.
(ii) These are generally smaller in size as compared to A-Chromosomes and are not homologous with any of the A-Chromosomes.
(iii) These are genetically inert.
(iv) They show non-Mendelian inheritance.
(v) The most important effect of these chromosomes is on seed and pollenfertility.

Certain specific terms

(i) **Karyotype:** The term karyotype is used for a group of characters, *i.e.*, number, size, shape, etc., that identifies a particular chromosome set.
(ii) **Idiogram:** Karyotype of a species is represented with the help of a diagram called idiogram.
(iii) **Genome:** Genome is defined as a haploid set of chromosomes or the chromosome number of a gamete constitutes genome.

oxygenase enzyme



$$\mathrm{H_2N{-}\underset{H}{\overset{R_1}{C}}{-}COOH + H_2N{-}\underset{H}{\overset{R_2}{C}}{-}COOH + \ldots \xrightarrow{-H_2O} H_2N{-}\underset{H}{\overset{R_1}{C}}{-}CONH{-}\underset{H}{\overset{R_2}{C}}{-}COOH + \ldots}$$

- All the protein amino acids (20 in number called Magic-20) are laevorotatory. The simplest of amino acids is Glycine and the most complex is **Tryptophan**. Asparagine was the first amino acid to be discovered from *Asparagus* plant.
- There are three sulphur containing amino acids—Cystein, Cystine and Methionine.
- There are seven nutritionally essential amino acids for man (necessary for survival, not synthesized in body)—Leucine, Isoleucine, Lysine, Methionine, Phenyl alanine, Tryptophan and Valine.
- Proteins are made of carbon (51%), oxygen (25%), nitrogen (16%), hydrogen (7%), sulphur (0.4%) and sometimes phosphorus is also present in traces.
- Proteins show **enormous diversity** because of different proportions and sequences of twenty amino acids within the protein molecules (a large number of permutations and combinations of these amino acids are responsible for the unlimited variety of proteins).
- On hydrolysis by protease enzyme, proteins yield amino acids. Proteins and amino acids are **amphoteric** in nature (*i.e.*, can react with both acids and bases to form salts).
- Proteins are oxidized by **putrefaction process** and the products are amino nitrogen compounds, CO_2 and H_2O. Bad smell is also emitted.
- Proteins are present as a colloidal solution in protoplasm and in solid form as protein granules in seeds. These are found in unit membranes and along with iron form cytochromes which are meant for electron transport system. Chlorophyll (green pigment of plants) is also a mixtures of Mg and proteins. Further, all enzymes are also proteins.
- Solubility of proteins varies. It is observed that albumins are soluble in distilled water, *e.g.*, leucosins in the seeds of cereals and ricin in castor oil seeds while globulins are soluble in dilute salt solutions of neutral pH, *e.g.*, legumin from peas and tuberin from potato tuber. Glutenin, a common protein of cereals, is soluble in acidic or basic solution while gliadin of wheat and zein of maize which are prolamines are soluble in alcoholic solution.
- Proteins also occur as storage substances in amorphous, crystal-like or in solid form, *e.g.*, aleurone grains (in cereals below seed coat). Each aleurone grain has a large crystalline portion called crystalloid which is proteinaceous and a small globular portion called globoid which is a double phosphate of calcium and magnesium.
- The most abundant protein is **Rubisco** (RuBP-carboxylase-oxygenase enzyme system), which constitutes 16% of total chloroplast protein.
- The sweetest substance is a protein called **thaumatin** followed by **monelin**.
- The smallest protein is **adrenocorticotropic hormone** (ACTH) having 39 amino acids and mol. wt. 4500. The largest protein is **pyruvate dehydrogenase** having 72 polypeptide chains and mol. wt. 46,00,000.
- Secondary structure (α-helix structure) of proteins was given by two Americans **Linus Pauling** and **Robert Correy** (1952) using X-ray diffraction technique in silk fibres. It deals with the folding of a polypeptide chain around an imaginary axis like a coil, establishing H-bond between the first and fourth amino acids. There are 3.6 amino acids per turn of the spiral and the pitch of the turn is 5.4 Å.
- Myoglobin and lysozyme are monomeric proteins, *i.e.*, having only one polypeptide chain.
- Biological functions of proteins include:
  - (a) **Enzymes:** All enzymes are proteins except ribozyme → are not proteins.
  - (b) **Storage proteins,** *e.g.*, zein of maize, gluten (glutelin and gliadin) of wheat, oryzenin of rice, albumin of egg, casein of milk, etc.
  - (c) **Transport protein,** *e.g.*, haemoglobin.
  - (d) **Defence proteins,** *e.g.*, immunoglobulins (anti-bodies).
  - (e) **Structural proteins,** *e.g.*, tubulin (forming micro-tubules).
  - (f) **Contractile proteins,** *e.g.*, myosin and actin.
  - (g) **Regulatory proteins,** *e.g.*, hormones like insulin and ACTH.
  - (h) **Toxins,** *e.g.*, venom of snakes.

(2) Secretory substances

The main secretory substances found in plants are:

(i) Colouring substances: The green colour of plants is due to the presence of **chlorophyll-a** and **chlorophyll-b** while yellow and orange colour of flower, fruits, seeds, etc., is because of two pigments, **xanthophylls** and **carotene**. Besides, **anthocyanins** present in the cell sap or vacuolar sap are responsible for the blue, purple and pink colours of **flowers, fruits, roots, leaves,** etc.

(ii) Nectar: Different parts of the flower secrete this sweet substance, which is a mixture of sucrose, glucose and fructose. Nectar attracts insects for pollination.

(iii) Enzymes or biological catalysts: Enzymes are specialized proteins, synthesized within a cell. These have a potentiality to accelerate the rate of chemical reactions (without undergoing any change in themselves).

- Existence of enzymes was predicted by **Berzelius** (1835) and the term 'Enzyme' (meaning: 'in yeast') was given by **Kuhne** (1878).

- E. Buchner reported 'zymase' in yeast which is responsible for fermentation. The chemistry of enzyme was known by J.B. Sumner (1926), who obtained the urease enzyme in crystallized form, from jack bean (*Canavalia gladiata*) meal.

Classification of enzymes: On the basis of type of reactions, catalysed by enzymes, these are divided into six groups: oxidoreductases, transferases, hydrolases, lyases, isomerases and ligases or synthetases.

Chemical nature of enzymes: It is now universally accepted that all enzymes are proteins. Proteins may be single or aggregate of polypeptide chains. The enzymes are broadly divided into two types:

(i) **Simple enzymes:** These are simple proteins, *i.e.*, having only protein part.

(ii) **Conjugated enzymes:** In these enzymes, the non-protein part is firmly attached to protein part. The protein part is called **apoenzyme** whereas the non-protein part is called **cofactor.**

- Apoenzyme + cofactor constitute holoenzyme (conjugated enzyme).
- Activity of enzymes is due to cofactor which can be separated by dialysis. After separation of cofactor, the activity of holoenzyme or conjugated enzyme is lost.
- Cofactor is small, heat stable and may be organic or inorganic in nature. Further, organic cofactors are of two types:

  (a) **Prosthetic groups:** Non-protein organic cofactors **firmly attached** to apoenzymes are called prosthetic groups, *e.g.*, heme, biotin, pyridoxyl phosphate. Heme is iron containing prosthetic group in cytochromes (electron carriers), haemoglobin, myoglobin, peroxidase and catalase.

  (b) **Coenzymes:** These are **loosely attached** non-protein organic cofactors or these are easily separable. Most of the coenzymes consist of water soluble vitamins B and C like thiamine, riboflavin, pyridoxine, nicotinamide, etc.

  Both prosthetic groups and coenzymes take part in group transfer reactions.

  Inorganic cofactors are variety of ions of minerals like Ca^{2+}, Fe^{2+}, Cu^{2+}, Mn^{2+}, Zn^{2+}, Mg^{2+}, etc., and these generally act as activators.

- All coenzymes are cofactors but all cofactors are not coenzymes.

Each enzyme is having a well marked cavity called **active site** where specific substrate is attached during reaction. Active site is made of a few amino acids and their side chain groups arranged in a particular fashion as a result of secondary and tertiary folding of polypeptide chain or protein molecule. More than one active site may be present in an enzyme.

Enzyme action: According to Michaelis and Menton (1913), the enzyme forms a complex with substrate during the reaction, called enzyme-substrate complex which then dissociates into products and enzyme.

$$\text{Enzyme + substrate} \rightleftharpoons \text{Enzyme-substrate complex} \xrightleftharpoons{\text{hydrolysis}} \text{End products + Enzyme}$$

- **Key-Lock theory** of enzyme action was given by Fischer, according to which, as a particular lock can be opened by a particular key, similarly a specific substrate molecule (key) can fit into the active site of an enzyme molecule (lock).
- **D.E. Koshland** *et al.* (1966) put forward the **induced fit** theory of enzyme action. According to this theory, an enzyme molecule has at least two sites with which the substrate molecules can combine. Attachment of substrate at one site causes a confirmational change in the enzyme which results in greater affinity of substrate at the other site. So according to this there is co-operative effect of substrate molecule.
- The important role that enzymes play in chemical reactions is that they decrease the energy of activation (energy which is needed in conversion of substrate to products).
- **Carbonic anhydrase** is the fastest enzyme known, which hydrates 36 million molecules of CO_2 per minute to form carbonic acid, *i.e.*, its **turn over number** (number of substrate molecules changed per minute by an enzyme molecule) is 3.6×10^7 or 36 million. This enzyme is present in RBCs.

Inhibition of enzyme action: Enzyme action can be inhibited in four different ways:

(a) **Denaturation:** High temperature destroys the activity of enzymes by causing their denaturation, *i.e.*, unfolding of polypeptide chain, which brings change in properties of proteins or enzymes.

(b) **Competitive inhibition:** Structural analogues of substrate molecules compete with normal substrate molecules for active site on the enzyme. Such substances acting in this manner are called competitive inhibitors and this inhibition of enzyme activity is called competitive inhibition, *e.g.*, malonic acid is a structural analogue or competitive inhibitor of succinic acid (substrate) on succinic dehydrogenase enzyme. It can be overcome by increasing the concentration of substrate molecules until all active sites are occupied.

(c) **Non-competitive inhibition:** Here inhibitors react either with parts of enzyme not involved in catalytic activity (thus modifying the enzyme structure) or with enzyme-substrate complex (which is rendered inactive).

(d) **Allosteric inhibition or feedback inhibition or allosteric modulation:** This is due to fitting of final end products or modulators or allosteric substances into allosteric site (away from active site) and thus bringing about a change in shape of enzyme so that active site becomes unfit for attachment of substrate molecules. Such enzymes are called allosteric enzymes and this inhibition is called allosteric inhibition.

(3) Excretory substances

These substances are useless for plants. The excretory sub-

Octamer Histones

- Somatic cells are having two haploid sets of chromosomes ($2n$) and hence two genomes.
- The smallest genome in plants is in *Haplopappus gracilis*, $n = 2$.

(iv) **Plasmon:** Hereditary factors or genes present in cytoplasm are called 'plasmon'.

- Genes present in plastids are called plastogenes and genes present in mitochondria are called chondriogenes.

CYTOPLASMIC INCLUSIONS OR NON-LIVING INCLUSIONS OR ERGASTIC SUBSTANCES OR DEUTOPLASMIC SUBSTANCES

Some metabolically inactive substances are formed inside the cell as a result of different metabolic activities in it. These substances are called metabolically inactive substances or deutoplasmic substances. These substances are divided into three groups:

(1) Reserve or storage substances,
(2) Secretory substances and
(3) Excretory substances.

substances

photosynthesis

(1) Reserve or Storage substances

These materials are formed inside the plants from CO_2 and H_2O and accumulate in different parts of the plant, mostly in stem, root, bud, etc.

These reserve materials are of three types:

(A) Carbohydrates

These are 'hydrates of carbon'. Carbohydrates are organic compounds which generally contain C : H : O in the ratio of 1 : 2 : 1, but there are some substances, *i.e.*, rhamnose ($C_6H_{12}O_5$) in which C, H, O are not in the ratio of 1 : 2 : 1 but still are carbohydrates.

Nowadays carbohydrates are defined as:

'Polyhydroxy aldehydes or ketones or the substances which on hydrolysis yield either aldehyde or ketone.'

Carbohydrates are important substances for plants as they give energy on oxidation.

If carbohydrates are heated, the residue of carbon is left and water evaporates.

Carbohydrates are of three types:

(i) **Monosaccharides:** These are the simplest of carbohydrates and are building units of complex carbohydrates. Monosaccharides are crystalline and sweet in taste. These cannot be hydrolysed. These are soluble in H_2O, sparingly soluble in ethanol and insoluble in ether. ROR ROH

- On the basis of number of C-atoms, the monosaccharides are of different types as **Trioses** (3C), *e.g.*, glyceraldehyde and dihydroxyacetone, **Tetroses** (4C), *e.g.*, erythrose and erythrulose, **Pentoses** (5C), *e.g.*, ribose, ribulose, xylose and xylulose, arabinose, **Hexoses** (6C), *e.g.*, glucose, fructose, mannose, galactose and **Heptoses** (7C), *e.g.*, sedoheptulose.
- Pentoses, *e.g.*, ribose, ribulose, xylose, xylulose and hexoses, *e.g.*, glucose (in grapes), fructose (in fruits) and mannose, etc., are common in plants.
- Hexoses are the most common sugars of plants. Further, the most abundant monosaccharide is glucose, which is also called grape sugar or corn sugar or blood sugar or dextrose (as it is dextrorotatory in nature, *i.e.*, its solution rotates the plane of polarized light towards right).
- The sweetest carbohydrate is fructose, which is also called fruit sugar because of its common occurrence in fruits (except grapes). It is also called levulose (because of its laevorotatory nature, *i.e.*, rotates the plane of polarized light towards left). It has a sweetening index of 170 (whereas the sweetening index of glucose is 70).
- Fructose or levulose is the major component of honey; hence it is also called honey sugar. Honey is having 40% fructose, 21% dextrose or glucose and 8% maltose.
- Galactose is called nerve sugar.

(ii) **Disaccharides or Oligosaccharides:** On hydrolysis oligosaccharides yield 2–6 monosaccharide units. These are crystalline, sweet in taste and are readily soluble in water.

- The common oligosaccharides are sucrose, maltose and lactose.
- Sucrose ($C_{12}H_{22}O_{11}$) or cane sugar is found in sugar cane (15–20%), beet root (10–20%) and plums (3–5%). On hydrolysis sucrose yields one molecule of glucose and one of fructose. Sweetening index of sucrose is 100.
- (Saccharine is an artificial sweetener, which is non-carbohydrate in nature. It is having no nutritive value. The sweetening index of saccharine is 400 times to that of sucrose, *i.e.*, 40,000. It is given to diabetics.)
- **Maltose:** Two α-D-glucose molecules are formed on hydrolysis of maltose. It is found in corn syrup. Malt prepared from sprouting barley is an excellent source of maltose.
- **Lactose** (milk sugar) is made of one molecule of glucose and one molecule of galactose joined through C-1 of galactose and C-4 of glucose.
- **Trisaccharides:** In sugar beet and cotton seed, a trisaccharide raffinose is found which on hydrolysis yields one molecule each of glucose, fructose and galactose.

(iii) **Polysaccharides:** These are complex of carbohydrates. On hydrolysis, these yield a large number of monosaccharides. These are tasteless, amorphous and insoluble in water.

Main polysaccharides in plants are:

(1) **Inulin:** It is made of 30–50 fructose units. Mostly found in family Compositae (Asteraceae).

- Commercial source of inulin is rhizomes of Jerusalem artichoke (*Helianthus tuberosus*).
- In roots of *Dahlia*, inulin is present in the form of **fan-like crystals**.

(2) **Starch:** Starch is the most important polysaccharide present as stored food in seeds, fruits and rhizomes of plants. It is made of a long chain of α-D-glucose units joined by α-1,4-linkages.

It is of two types:

Temporary starch: It is formed in the process of photosynthesis during daytime and is converted into sucrose at night.

1st carbon of one molecule link to 4th carbon 2nd molecule

Permanent starch: Sugars are converted into permanent starch after a certain level.

- Starch is composed of **amylose** (15–20%) which is present in centre and **amylopectin** (80–85%) present towards the periphery.
- Amylose is made of unbranched chain of α-D-glucose units joined by α-1,4-glycosidic linkages, whereas amylopectin is branched having both α-1,4-linkages as well as α-1,6-linkages.

Starch occurs in the form of starch grains.

The shape and size of starch grain differ.

Each grain consists of a shining body called hilum around which the layers of starch are deposited in different ways or patterns. Starch grains are of two types:

(a) **Eccentric:** Hilum is present at periphery and starch layers are formed on one side of the hilum, *e.g.*, in potato tubers.

(b) **Concentric:** Hilum is present in the centre and the layers are deposited around it, *e.g.*, wheat, maize, pea, etc.

Depending upon the number of hilum, starch grains are of two types:

(i) **Simple starch grains** have single hilum, *e.g.*, potato, pea, maize, etc.

(ii) **Compound starch grains** have many hila, *e.g.*, banana, rice, oat, etc.

(3) **Glycogen or Animal starch $(C_6H_{10}O_5)_n$:** This is commonly found in animals, blue-green algae, bacteria, fungi and slime moulds. Glycogen is insoluble in water. It is a branched chain polymer of α-D-glucose units (5,000–30,000), but the chain is shorter than amylopectin.

(4) **Cellulose:** It is the structural component of cell wall and made up of long, unbranched chain of β-D-glucose molecules joined by β-1,4-linkages. It is the most abundant biomolecule and is present in cell walls of plants. Man cannot digest cellulose because cellulose digesting enzyme, cellulase/β-amylase is absent.

(5) **Pectin:** It is a polymer of galacturonic acid, arabinose and galactose.

- Pectin is a major constituent of middle lamella and helps in cementing adjacent cells. During ripening of fruits, pectate of middle lamella breaks due to which fruits become soft.
- Pectin absorbs water readily and because of this quality it is used for making jams and jellies.

(6) **Chitin:** It is a linear polymer of glucose derivative called N-acetylglucosamine (NAG), found in the cell wall of fungi. It is the **second most abundant** biomolecule.

(7) **Callose:** It is an amorphous polymer of β-D-glucose and it blocks the sieve pores of sieve plates in sieve tubes of phloem during winter.

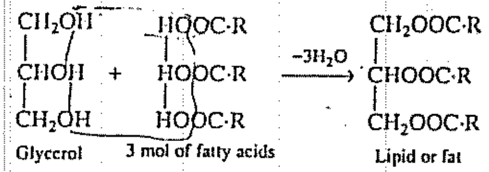
(8) **Gums and mucilages:** These are soluble in water and check the easy evaporation of water. They become slippery after being wet.

Reducing and non-reducing sugars: Carbohydrates with free aldehyde (—CHO) or ketonic group (C=O) are called reducing sugars because on treating with some metallic solutions like Fehling's solution and Benedict's solution, they get oxidized and reduce these reagents, *e.g.*, all monosaccharides and some disaccharides like lactose and maltose. This reaction is used in detecting sugar in urine.

The carbohydrates or sugars where free aldehyde or ketonic group is absent (utilized in glycosidic bond formation) and hence cannot reduce the above reagents, are called non-reducing sugars, *e.g.*, sucrose, glycogen, starch, etc.

(B) Lipids or Fats or Oils

Lipids or fats are esters of high molecular weight fatty acids and glycerol.



These are insoluble in water and soluble in organic solvents, *e.g.*, chloroform, acetone and ether.

- Lipids or fats are poorer in oxygen and hence require more O_2 for their oxidation.
- These are insoluble in H_2O so stored in cells without disturbing the osmotic relation.
- Lipids on oxidation provide maximum energy as compared to carbohydrates and proteins.
- In plants, fats are liquid at room temperature, called **'oils'**. These oils contain unsaturated fatty acids like **oleic acid** ($C_{17}H_{33}COOH$), **linolic acid** ($C_{17}H_{31}COOH$) and **linolenic acid** ($C_{17}H_{29}COOH$), etc.
- By hydrogenation of oils (*i.e.*, by passing H_2 gas in presence of Ni catalyst), vegetable fats (solid) are produced, which is the basis of vegetable ghee industry.
- Lipids are components of unit membranes (especially phospholipids).
- Phospholipids or lipid molecules are **amphipathic** in nature (*i.e.*, having both polar and non-polar ends).
- In certain plants (xerophytes), waxy covering or coating is present. Waxes in turn are esters of monohydric alcohol and fatty acids.

(C) Nitrogenous substances

Proteins: All living cells have proteins in one form or other. Proteins are polymers of high molecular weight and amino acids being the monomeric units. These amino acids are linked together by a **peptide bond** (—CONH) and there are many peptide bonds in a single protein molecule; so proteins are also called polypeptides.

stances are accumulated in old leaves, bark, etc., and are removed to get rid of these metabolic wastes. The chief excretory substances of plants are:

(A) **Alkaloids:** These are nitrogen containing substances having C, H, O and N and occur in storage organs (seed, bark and leaves) in combination with organic acids. Alkaloids occur in vacuoles or in cytoplasm in solid form.

The term alkaloid (alkali like) was first used by W. Meissner (1819) and their chemistry was given by Serterner (1805).

Alkaloids are insoluble in water and soluble in alcohol. About 4500 alkaloids are known, mostly from dicots.

- All members of family Papaveraceae are known to contain alkaloids which protect against fungi, bacteria and insects.

Alkaloids are of sour taste and are used in medicines. Some important alkaloids are:

(i) Morphine from unripe capsules of *Papaver somniferum* (opium or poppy).
(ii) Quinine from bark of *Cinchona*.
(iii) Reserpine from roots of *Rauwolfia*.
(iv) Nicotine from leaves of tobacco (*Nicotiana tabaccum*).
(v) Caffein from seeds of coffee (*Coffea arabica*).
(vi) Colchicine from roots of *Colchicum autumnale*.
(vii) Thein from leaves of tea, *Camellia sinensis*.
(viii) Atropine from roots of *Atropa belladona*.

(B) **Gums:** These are decomposition products of cellulose and the process of formation of gums is called **gumosis**. These are soluble in water and have adhesive property. Gums are also used in medicines. The most important gum is **gum arabic** obtained from *Acacia senegal* (family Mimosaceae).

(C) **Glucosides:** These are degradation products of carbohydrates. Glucosides control acidity and alkanity of cells. These are also used as drugs, *e.g.*, **Digitoxin** obtained from leaves of *Digitalis purpurea* and used in heart diseases.

(D) **Essential oils:** These are those oils which evaporate in contact with air and are present in specialized oil glands. As these are having smell so help in entomophilly (pollination by insects), *e.g.*, in leaves of *Ocimum, Citrus, Eucalyptus, Cymbopogon*, petals of rose, jasmine, lavender, unopened flower buds of clove and wood of *Santalum*, etc.

(E) **Resins:** These are formed by oxidation of essential oils. Resins are insoluble in water and soluble in organic solvents like ether and alcohol. These are also used in paints and varnishes. Hing of commerce is a resin obtained from roots of *Ferula asafoetida*.

(F) **Latex:** It is a yellow, white or reddish, viscous fluid made of suspension of proteins, sugars, gums, enzymes, alkaloids, etc. It is present in latex vessels or cells, present in stem or leaves, *e.g.*, para rubber or hevea rubber obtained from *Hevea brasiliensis* (family Euphorbieaceae).

- Latex of papaya possesses papain enzyme used for digestion of proteins. Similarly white latex is also found in *Calotropis, Ficus, Euphorbia*, whereas yellowish latex is present in *Argemone, Papaver* and *Musa*.

(G) **Tannins:** These are phenolic compounds which are related to glucosides and show acidic reaction. Tannins are having sour or bitter taste and are found in cell sap, cell wall, bark, leaves, wood and fruits (specially unripe fruits). Tannins form blue-black colour with iron salts like ferric chloride and thus is the basis of blue-black inks. These are also used in leather industry and medicines. Important sources of tannins are heart wood of *Acacia catechu* which provides kattha or khair used as dye in betel leaves. Haematoxylin stain is obtained from the wood of *Haematoxylon campechianum*. Similarly tannins are found in large amounts in fruits of *Terminalia* (myrobalans), leaves of tea, fruits of *Emblica officinalis* (amla).

(H) **Organic acids:** These are present abundantly in vegetables and fruits, *e.g.*, citric acid in *Citrus* fruits, tartaric acid in fruits of *Tamarindus* (imli), oxalic acid in *Oxalis*, etc.

(I) **Mineral crystals:** The main crystals found in plant cells are of calcium carbonate, calcium oxalate and silica.

(i) **Crystals of calcium carbonate:** The crystals of calcium carbonate are present in leaves of banyan (*Ficus benghalensis*), Indian rubber plant (*Ficus elastica*). The crystals of calcium carbonate are present in leaves of *Ficus* (banyan) in the form of bunch of grapes, which are called **cystolith**.

(ii) **Calcium oxalate:** These crystals are mostly present in storage tissues like pith and cortex. These are of different shapes like prismatic, pyramidal, needle-like, rod-like, etc.

- Needle-like or acicular crystals of calcium oxalate are called **raphides** and are found in *Pistia, Eichhornia* and also in different aroids (members of family Araceae), *e.g., Colocasia, Amorphophalus*, etc.
  Raphides are generally present in **Idioblasts**, *i.e.*, mucilage containing cells.
- Calcium oxalate crystals are sometimes present in groups to form spherical or star-like structures which are called **sphaeroraphides** or **sphaerocrystals** or **druses**. These druses are found in papaya, *Pistia* and *Colocasia*, etc.

(iii) **Silica:** Small silica crystals are present singly in vacuoles, cell lumen of *Atropa belladona* (Solanaceae). It is also called crystal sand.

Silica
Latex
Lai Latex. Latex
Resins

DIFFERENCES BETWEEN PLANT AND ANIMAL CELL

	Plant cell	Animal cell
1.	The outermost covering of the plant cell is a **thick, rigid, non-living cell wall**. It is made up of cellulose and on its inner side, plasma membrane is present.	Cell wall is absent and the outermost covering is **thin, flexible, living plasma membrane.**
2.	In a mature cell, a large single vacuole is present in centre.	Vacuoles are absent in most of animal cells, if present, they are very small.
3.	The centrally located Large vacuole pushes the nucleus towards periphery.	Nucleus is generally present in centre.
4.	Except some lower plants, *e.g.*, algae, fungi, etc., the centrosome is absent.	Centrosome is present and helps in cell division.
5.	Plastids are present.	Plastids are absent.
6.	Mitochondria are generally less in number.	Mitochondria are present in large number.
7.	The cristae of mitochondria are tubular.	The cristae are plate-like in an animal cell.
8.	Glyoxysomes are present in some cells.	Glyoxysomes are absent.
9.	In some plant cells, crystals are present.	Crystals are absent in animal cells.
10.	Contractile vacuoles are absent.	Excess of water is removed with the help of contractile vacuoles.
11.	Synthesis of various substances, *i.e.*, amino acids, coenzymes, vitamins is carried out in a plant cell.	All these substances are not synthesized in animal cell.
12.	Plant cells are generally more than 100 μm in length.	Animal cells are generally less than 100 μm in length.
13.	Division of cytoplasm or cytokinesis is by **cell plate** method which is formed by **phragmoplasts** provided by Golgi bodies. Further this is centrifugal, *i.e.*, formed from centre to periphery.	Division of cytoplasm is by **cell furrow** method and this furrow or constriction is formed from periphery to centre, *i.e.*, centripetally.
14.	During cell division the spindle has an aster at each pole, *i.e.*, **amphiastral.**	Spindle formed during cell division is without asters, *i.e.*, **anastral.**

545

MULTIPLE CHOICE QUESTIONS

1. Which is differentially permeable?
(a) Cell wall (b) Middle lamella
[✓ (c) Cell membrane] (d) Cuticle

2. Which of the following is the smallest and least complex unit of matter, which can be called living?
[✓ (a) Cell] (b) Nucleus
(c) Mitochondria (d) Virus

3. Feulgen reagent is used to stain:
(a) RNA (b) Proteins
[✓ (c) DNA] (d) Carbohydrates

4. Smallest number of chromosomes ($2n = 4$) occurs in:
(a) *Ophioglossum* (b) *Pteris*
(c) *Haplopappus* (d) *Salvinia*

5. Protoplasm is actually a:
(a) Solution (b) Compound
(c) Mixture [✓ (d) Colloid]

6. When SAT-chromosomes contain second satellite, then they are called:
(a) Double SAT (b) Trabant SAT
[✓ (c) Tandem SAT] (d) None of these

7. In which of the following DNA is concentrated?
(a) Cell wall (b) Nucleolus
[✓ (c) Chromosome] (d) Plasma membrane

8. The absorption of dead cells is brought about by:
(a) ER [✓ (b) Lysosomes]
(c) Vacuole (d) Golgi apparatus

9. Which one of the following cell organelle remains enveloped by single unit membrane? (MPPMT 1995)
(a) Mitochondria (b) Plastid
(c) Ribosome [✓ (d) Lysosome]

10. Protoplasm undergoes coagulation, which results in total stoppage of all physiological activities at:
[✓ (a) 60°C] (b) 50°C
(c) 70°C (d) 75°C

*11. Who stated that cell is the basic unit of all plants?
(a) Swanson (b) Schwann
(c) Virchow [✓ (d) Schleiden]

hydrolytic enzymes

12. Thickness of plasma membrane is: (MPPMT 1994)
(a) 200 nm [✓ (b) 7.5 nm]
(c) 150 nm (d) 1.0 nm

13. Which one of these gives mechanical support to cell?
(a) Cilia (b) Lysosome
[✓ (c) ER] (d) Golgi bodies

14. The unit for measurement of sedimentation of ribosome is:
[✓ (a) Svedberg (S)] (b) Angstrom (Å)
(c) Micron (μ) (d) Nanometre (nm)

15. Extranuclear DNA is found in:
(a) Lysosomes (b) Golgi bodies
[✓ (c) Mitochondria] (d) None of these

16. Hammerling performed experiments to prove that nucleus is physical basis of heredity by working on: (Kerala PMT 2003)
(a) *Neurospora* (b) *Drosophila*
[✓ (c) *Acetabularia*] (d) *Amoeba*

17. Proteins are synthesized by:
[✓ (a) Ribosomes] (b) Mitochondria
(c) Golgi bodies (d) Centrosomes

18. The ribosome of 70S sediment coefficient breaks into 2 subunits of:
(a) 50S and 20S (b) 50S and 40S
[✓ (c) 50S and 30S] (d) 60S and 40S

19. Which is the exception to cell theory?
(a) Bacteria (b) Mycoplasma
[✓ (c) Viruses] (d) None of these

20. Lysosomes are called suicide-bags because of:
(a) Phagocytic enzymes [✓ (b) Hydrolytic enzymes]
(c) Proteolytic enzymes (d) Respiratory enzymes

21. According to fluid mosaic model, plasma membrane presents:
[✓ (a) A quasi fluid structure] (b) A miceller structure
(c) A polar structure (d) Unit membrane structure

*22. A cluster of ribosomes held together is called:
(a) Mesosome (b) Dictyosome
[✓ (c) Polysome] (d) Microsome

23. What Robert Hooke (1665) first observed under microscope as a cell was in fact: (CBSE 2003)
(a) Plasma membrane (b) Cell membrane
[✓ (c) Cell wall] (d) Cytoplasm

24. Membranous units forming a series of continuous and discontinuous cavities in cell are called:
(a) Plasmodesmata (b) Plasmalemma
[✓ (c) Endoplasmic reticulum] (d) Chromatin network

25. Molecular model of plasma membrane was proposed by:
(a) Watson and Crick [✓ (b) Danielli and Davson]
(c) Skoog and Miller (d) Singer and Nicolson

26. The lysosome enzymes are basically:
[✓ (a) Acid hydrolase type] (b) Dehydrogenase type
(c) Carboxylase type (d) Oxidase type

27. A single mitochondrion is found in:
(a) *Micrococcus* (b) *Rhizopus*
(c) *Nostoc* (d) *Microsterias*

28. Function of centriole is:
[✓ (a) Formation of spindle fibres]
(b) Formation of nucleolus
(c) Initiation of cell division
(d) Formation of cell plate

29. Autosome is: (Jharkhand CECE 2003)
(a) Acromatic
(b) Sex chromosome
[✓ (c) Chromosome other than sex chromosome]
(d) Not a chromosome

30. Ribosomes were first discovered by: (CPMT 1990)
(a) Benda (b) Swanson
(c) Altmann (d) Palade

31. The oxysomes are made of:
(a) Glycoproteins [✓ (b) Lipoproteins]
(c) Phosphoproteins (d) None of these

32. The diameter of ribosomes varies from:
(a) 100–150 Å (b) 60–100 Å
[✓ (c) 200–240 Å] (d) 200–320 Å

33. RNA is absent in:
(a) Cytoplasm (b) Chromosomes
(c) Ribosomes [✓ (d) Plasmalemma]

34. Mitochondria are called power house of the cell, because these:
(a) Contain enzymes [✓ (b) Release ATP]
(c) Contain ribosomes (d) Contain RNA and DNA

35. Colloidal theory of protoplasm has been given by:
(a) Palade (b) Altmann
(c) Flemming [✓ (d) Fischer]

36. Hydrophobic ends of phospholipid molecules are:
(a) Polar (b) Neutral
[✓ (c) Non-polar] (d) Bipolar

37. Which is not a membrane bound structure? (DPMT 2003)
[✓ (a) Centriole] (b) Nucleus
(c) ER (d) None of these

38. The term 'chromosome' was introduced by: (CPMT 1992)
(a) Strasburger (b) Benda
(c) Hoffmeister [✓ (d) Waldeyer]

39. Chromosomes are made up of structural units called:
(a) Nucleoli (b) Endosomes
[✓ (c) Nucleosomes] (d) Centrosomes

40. Non-living substances of cells are collectively known as:
(a) Cytoplasm (b) Plasmagel
(c) Mesoplasm [✓ (d) Deutoplasm]

41. Which is the smallest cell organelle?
(a) Lysosome (b) Sphaerosome
(c) Peroxisome [✓ (d) Ribosome]

42. Centromere is required for: (CBSE 1994)
[✓ (a) DNA duplication]
(b) Cytoplasmic cleavage
(c) Chromosome segregation
(d) Poleward movement of chromatids

43. Lysosome along with food content is known as:
(a) Primary lysosome [✓ (b) Secondary lysosome]
(c) Residual body (d) Microbody

***44.** Which cell structure occurs in epidermal cells of humans but not in epidermal cells of leaves?
[✓ (a) Centriole] (b) Mitochondria
(c) Cell membrane (d) Chromosome

45. Characteristic size and shape of chromosomes of an organism at mitotic metaphase is known as:
(a) Genotype (b) Genome
[✓ (c) Karyotype] (d) Phenotype

46. Centromere is also called:
(a) Secondary constriction [✓ (b) Primary constriction]
(c) Satellite body (d) Locus

47. Protoplasm is:
(a) Colloidal solution
(b) Suspension
(c) True solution
(d) Polyphasic colloidal system

48. ER was discovered by:
(a) Sutton [✓ (b) Porter]
(c) De Barry (d) Palade

49. The term 'Microsome' was given by:
(a) Palade (b) Claude
(c) Singer (d) None of these

50. 'Microsome' formed from:
(a) Ribosomes (b) ER
(c) Golgi bodies [✓ (d) All of these]

51. Plane of new cell wall formation in a dividing cell is determined by:
(a) Microfilaments [✓ (b) Microtubules]
(c) ER (d) Golgi apparatus

52. Plastids contain:
(a) Cristae (b) Microtubules
(c) Porous membrane [✓ (d) Thylakoids]

53. The dark stained regions in a chromosome are known as:
(a) Heterochromatin [✓ (b) Euchromatin]
(c) Idiogram (d) Plectonema

54. A normal plant suddenly started reproducing parthenogenetically; the number of chromosomes of second generation compared to parent plant will be:
(a) Double [✓ (b) Half]
(c) Same (d) None of these

55. 'Quantasomes' were discovered by:
(a) Fraenkal Conrat (b) Temin and Baltimore
(c) Lederburg and Tatum [✓ (d) Park and Biggins]

56. Which of the following is 'semi-autonomous'?
(a) Lysosome (b) Sphaerosome
(c) Peroxisome [✓ (d) Mitochondria]

57. Karyotype of an organism is represented by a diagram called:
(a) Histogram (b) Histrogram
[✓ (c) Idiogram] (d) Telegram

58. Phycoerythrin is present in:
(a) Leucoplast (b) Elaioplast
[✓ (c) Rhodoplast] (d) Amyloplast

59. Sphaerosomes are associated with:
(a) Protein metabolism [✓ (b) Lipid metabolism]
(c) Nitrogen metabolism (d) Glycolate metabolism

60. All the activities of cell are guided by:
(a) Ribosomes (b) Cytoplasm
[✓ (c) Nucleus] (d) Mitochondria

61. The ends of chromosomes are called:
(a) Centromere [✓ (b) Telomere]
(c) Chromomere (d) None of these

62. Microtubules were discovered by:
(a) Watson and Crick [✓ (b) De Robertis and Franchi]
(c) Jacob and Monad (d) Zinder and Laderburg

***63.** The chief role of lysosome is:
(a) Secretion (b) Respiration
(c) Extracellular digestion [✓ (d) Intracellular digestion]

64. The term 'cell' was given by: (CPMT 2003)
(a) Virchow (b) Leeuwenhoek
(c) Malpighi [✓ (d) Hooke]

65. According to cell theory:
[✓ (a) All organisms are made of cells]
(b) All cells have nuclei
(c) All cells reproduce by mitosis
(d) All cells must undergo meiosis

66. In plant cells, dictyosomes are involved in production of:
(a) Nuclear membrane material
[✓ (b) Cell wall material]
(c) Vacuolar membrane material
(d) All of the above

67. The nuclei arise from pre-existing nuclei was suggested by:
(a) Strasburger (b) Hoffmeister
(c) Van Beneden (d) Hertwig

68. Length of chromosome is directly proportional to:
(a) Size of organism (b) Size of nucleus
(c) Size of DNA [✓ (d) No. of genes]

69. Which of the following is most abundant in plants?
(a) Starch [✓ (b) Cellulose]
(c) Glucose (d) Sucrose

70. Lysosomes occur mostly in:
(a) Algae (b) Bacteria
(c) Plants [✓ (d) Animals]

*71. Which of the following is not a biological property of life?
[✓ (a) Brownian movement] (b) Growth
(c) Reproduction (d) Responsiveness

72. Out of the total enzymes present in cell, mitochondria alone have:
(a) 95% [✓ (b) 70%]
(c) 40% (d) No enzymes

73. Stroma is the ground substance of:
(a) Lysosome (b) Ribosome
[✓ (c) Chloroplast] (d) Mitochondria

74. Ribosomes are centres of:
[CBSE 2000; BCECE (P.T.) Exam. 2002]
(a) Anaerobic respiration (b) Starch synthesis
[✓ (c) Protein synthesis] (d) Fat synthesis

75. Basic mechanism of hereditary transmission is:
[✓ (a) Sexual reproduction]
(b) Polyploidy
(c) Splitting of chromosomes
(d) Mitosis

76. Chromosome is made of:
(a) DNA (b) DNA and proteins
[✓ (c) DNA, RNA and proteins] (d) RNA and proteins

77. Which element is present at the centre of chlorophyll molecule: (CMC, Vellore 2003)
(a) Ca [✓ (b) Mg]
(c) Fe (d) Mn

78. Cells arise from pre-existing cells, advocated by:
(a) Dutrochet (b) Schleiden and Schwann
(c) Virchow (d) Jean Brachet

*79. Smallest cells so far observed are of:
(a) Bacteria (b) Viruses
[✓ (c) PPLO] (d) Yeast

80. J. Hammerling worked on *Acetabularia*, which is:
(a) Multicellular green alga (b) Unicellular fungus
[✓ (c) Unicellular green alga] (d) None of these

81. Which is responsible for origin of Plasmodesmata?
(a) Golgi bodies (b) Pits
[✓ (c) ER] (d) None of these

82. Wax-like fatty substance deposited on epidermal cells is:
(a) Lignin [✓ (b) Cutin]
(c) Suberin (d) Mucilage

83. 'Rough touch' of *Equisetum* is due to:
(a) Cutin (b) Lignin
(c) Suberin [✓ (d) Silica]

84. Which is exoskeleton of plant cell?
(a) ER (b) Golgi bodies
(c) Plasma membrane [✓ (d) Cell wall]

85. Oil cavities in citrus are:
(a) Schizogenous cavity [✓ (b) Lysogenous cavity]
(c) Schizolysigenous cavity (d) None of these

86. The famous unit membrane model was given by:
(a) Davson and Danielli (b) Robertson
(c) Singer and Nicolson (d) None of these

87. 'Fluid mosaic model' of plasma membrane was given by: (AFMC 1998; BHU 2001)
(a) Du Praw (b) Danielli
(c) Robertson [✓ (d) Singer and Nicolson]

88. The membrane of ER is:
(a) Permeable (b) Semipermeable
[✓ (c) Selectively permeable] (d) Impermeable

*89. The anthocyanins are present in:
(a) Cytoplasm (b) Cell wall
(c) Chloroplast [✓ (d) Cell sap]

90. The pigment which comes out of leaf on boiling in H_2O is:
(a) Xanthophyll (b) Carotene
[✓ (c) Anthocyanin] (d) Chlorophyll

91. The name 'Sarcode' to protoplasm was given by:
(a) Purkinje (b) Max Schultz
(c) Dujardin (d) None of these

92. In plant protoplasm, percentage of proteins is about:
(a) 2% (b) 1%
(c) 15% [✓ (d) 7%]

93. The term 'chloroplast' was given by:
(a) Haeckel (b) Hanstein
(c) Schimper (d) Caventou

94. Light reaction of photosynthesis occurs in which fraction of chloroplast?
(a) Stroma [✓ (b) Grana]
(c) Both (a) and (b) (d) None of these

95. Semi-autonomous nature of chloroplast is due to:
(a) DNA
(b) DNA and RNA polymerases
(c) Ribosomes
[✓ (d) All of the above]

96. The term 'Chlorophyll' was given by:
(a) Schimper (b) Caventou
(c) Stall (d) None of these

97. Molecular formula of Chl-a is:
[✓ (a) $C_{55}H_{72}O_5N_4Mg$] (b) $C_{55}H_{70}O_5N_4Mg$
(c) $C_{55}H_{70}O_6N_4Mg$ (d) $C_{55}H_{72}O_6N_5Mg$

98. Which pigment has a dominant role in photosynthesis?
[✓ (a) Chl-a] (b) Chl-b
(c) Chl-c (d) Carotenoids

99. Ribosomes of chloroplast are of the type:
(a) 60S [✓ (b) 70S]
(c) 80S (d) 120S

Suberin wax mucilage

$C_{55}H_{72}O_5N_4Mg$

100. Robert Hooke published the figures of cork cells in the book:
(a) *Origin of Species* (b) *Photographia*
(c) *Micrographia* (d) *Philosophia Botanica*

*101. Prokaryotic genetic system (genome) contains:
(a) DNA and histones (b) DNA or histones
[✓ (c) DNA but no histones] (d) Neither DNA nor histones

102. The main protein of cilia and flagella is:
(a) Actin (b) Albumin [✓ (c) Tubulin] (d) Gliadin

103. Nucleoid is found in:
(a) Plant cells
(b) Bacterial cells
[✓ (c) Bacterial cells and cyanobacteria]
(d) Plant cells, bacteria and blue-green algae

104. An organelle contains high concentration of catalase enzyme, the organelle is:
(a) Lysosome (b) Glyoxysome
[✓ (c) Peroxisome] (d) None of these

105. The dictyosomes play a major role:
(a) As energy transducing organelles
(b) In digesting proteins and carbohydrates
(c) In converting light energy into chemical energy
[✓ (d) In glycosidation of lipids and proteins to produce glycolipids and glycoproteins]

106. The resin duct of *Pinus* is a: (Raj. PMT 2001)
[✓ (a) Schizogenous cavity] (b) Lysigenous cavity
(c) Schizolysigenous cavity (d) None of these

107. The enzymes for conversion of fats into carbohydrates are provided by:
(a) Golgi complex (b) Lysosomes
[✓ (c) Glyoxysomes] (d) Lomasomes

108. Autonomic genome system occurs in:
(a) Ribosomes and chloroplast
(b) Mitochondria and ribosomes
[✓ (c) Mitochondria and chloroplast]
(d) None of the above

*109. The correct sequence of cell membrane as per model of Singer and Nicolson is: (AIIMS 1999)
(a) L-P-P-L (b) P-L-L-P
[✓ (c) P-P-L-P] (d) L-P-L-P

110. ATP driven H-pump is present in which organelle?
(a) Mitochondria [✓ (b) Lysosome]
(c) Chloroplast (d) Peroxisome

*111. Starch and cellulose are made of:
(a) Glucose and fructose respectively
[✓ (b) Glucose]
(c) Fructose
(d) Glucose and galactose respectively

112. In the saccules of Golgi bodies, the concave side (*trans*-face or maturity face) is facing:
(a) Nucleus [✓ (b) Cell membrane]
(c) Either of two (d) No such face

113. Lysosomes are present in red mould (*Neurospora*), was first demonstrated by: (Pb. PMT 2003)
(a) Beevers (b) Tolbert
(c) Matile (d) Porter

114. Which was discovered by Tolbert?
(a) Glyoxysomes (b) Lomasomes
(c) Peroxisomes (d) Sphaerosomes

115. Which organelle is associated with a wasteful process in only C-3 plants? (BHU 2001; Pb. PMT 2003)
(a) Mitochondria (b) Lysosomes
[✓ (c) Peroxisomes] (d) Sphaerosomes

116. Sphaerosomes can be best observed in:
(a) Wheat (b) Potato
(c) Arachis (d) None of these

*117. Diplosomes are the structures found in:
(a) Ribosomes [✓ (b) Centrosome]
(c) Plasma membrane (d) Cilia

118. Undulatory movements are shown by:
(a) Cilia (b) Flagella
(c) Both (a) and (b) (d) None of these

119. A dimer formed by union of two ribosomes is having sedimentation coefficient of:
(a) 160S (b) 120S
(c) 140S (d) 80S

*120. Which is absent in Ribosomes?
(a) Protein (b) Lipid
(c) RNA (d) None of these

121. Ribosome is attached to ER by:
(a) Smaller unit
(b) Larger unit
(c) Either by larger or smaller unit
(d) By both units

122. RNA in ribosomes is mostly:
(a) Single stranded (b) Double stranded
(c) Triple stranded (d) None of these

123. A plant cell vacuole contains: (CPMT 1991)
(a) Water
(b) Cytoplasm
(c) Air
(d) Water and dissolved substances

124. Which chemical is abundantly present in middle lamella?
(a) Suberin (b) Cutin
(c) Pectin (d) Lignin

125. Starch grains in potato tuber are located in:
(a) Chromoplasts (b) Leucoplasts
(c) Elaioplasts (d) Chloroplasts

126. Two compounds characteristic of plants and not of animals are:
(a) Glucose and pyruvic acid
(b) Glucose and cellulose
(c) Cellulose and starch
(d) Starch and pyruvic acid

127. Cystolith is a deposit of: (Raj. PMT 2001; DPMT 2003)
(a) Calcium oxalate (b) Starch
(c) Silica (d) Calcium carbonate

128. Mitochondria are absent in: (MPPMT 1994)
(a) Yeast (b) Bacteria
(c) Fungi (d) Green algae

129. Ribosomes are attached to ER through:
(a) r-RNA (b) t-RNA
(c) Hydrophobic interaction (d) Ribophorins

195. Which of the following is widely used as metal cofactor?
(a) Mg^{2+}
(b) Al^{3+}
(c) Ni^{2+}
(d) Ca^{2+}

196. Protein molecule is:
(a) Acidic
(b) Alkaline
(c) Amphoteric
(d) Amphipathic

197. Zwitter ion formation occurs in:
(a) Carbohydrate
(b) Lipid
(c) Protein
(d) None of these

198. When protein is heated, it is:
(a) Hydrolysed
(b) Putrefied
(c) Denatured
(d) None of these

199. The details of secondary and tertiary structures of proteins were worked out by:
(a) Pauling and Correy
(b) Watson and Crick
(c) Singer and Nicolson
(d) Wilkins and Franklin

***200.** Protoplasm consists of:
(a) Only living organelles
(b) Non-living structures
(c) Both living and dead structures
(d) Both living and non-living organelles

201. Physical basis of life is:
(a) Protoplasm
(b) Food
(c) Cell
(d) Nucleus

202. 'Father of Modern Cytology' is: (AFMC 1992)
(a) Schleiden and Schwann
(b) Robert Hooke
(c) O. Hertwig
(d) C.P. Swanson

203. Who has applied cell theory to plants?
(a) Jansen
(b) Schleiden
(c) Schwann
(d) Swanson

204. The major organic constituents of protoplasm are:
(a) Carbohydrates
(b) Water
(c) Nucleic acid
(d) Proteins

205. The intrinsic proteins in a membrane can be easily removed because they have:
(a) Weak hydrophobic bonds with lipids
(b) Weak hydrophilic bonds with lipids
(c) Both (a) and (b)
(d) Affinity for all solvents

206. The term protoplasm was given by:
(a) Robert Hooke
(b) Dujardin
(c) Purkinje
(d) Hugo von Mohl

207. Cell organelles are embedded in: (AMU 1991)
(a) Cytoplasmic membranes
(b) Mucein
(c) Protoplasm
(d) Cytoplasm

208. Entry of ions through plasmalemma takes place by:
(a) Carriers
(b) Cytochrome pumps
(c) Phosphatidic cycle
(d) All of these

209. Cell membrane is:
(a) Permeable
(b) Impermeable
(c) Semipermeable
(d) Porous

210. Which of the following proteins are non-structural and non-fibrillar in nature?
(a) Myosin
(b) Keratin
(c) Collagen
(d) Globulin

211. Zwitter ion effect is exhibited by:
(a) Carbohydrates
(b) Nucleic acid
(c) Enzymatic proteins
(d) Lipids

212. Who defined protoplasm as physical basis of life?
(a) Watson
(b) Dujardin
(c) Schwann
(d) J. Huxley

***213.** Hyaloplasm is:
(a) Protoplast is a hyaloplasm
(b) Protoplast + organelles = hyaloplasm
(c) Protoplast – organelles = hyaloplasm
(d) None of the above

214. Cell theory was propounded by: (MPPMT 2002)
(a) Schleiden and Schwann
(b) Robert Hooke
(c) Robert Koch
(d) Darwin

215. The substance which make up about 80% of cytoplasm in plant cells is:
(a) Mineral
(b) Water
(c) Protein
(d) Fats

216. The branch which deals with the study of cell structure is known as:
(a) Histology
(b) Ecology
(c) Morphology
(d) Cytology

217. Prokaryotic cell does not possess:
(a) Cytoplasm
(b) Plasma membrane
(c) Nuclear membrane
(d) Cell wall

218. What is the best estimate of average width of an onion cell?
(a) 0.007 mm
(b) 0.023 mm
(c) 0.075 mm
(d) 0.010 mm

219. Viscocity of cytoplasm is:
(a) 2 centipoise
(b) 100 centipoise
(c) 10 centipoise
(d) 20 centipoise

220. What electrical changes take place when the sol structure is converted into gel?
(a) All positive charges become converted into negative
(b) All negative charges become converted into positive
(c) All positive and negative charges become neutralized
(d) Neutralized state is converted into charged state

221. True nucleus is absent in:
(a) Bacteria
(b) Green algae
(c) Fungi
(d) Lichens

***222.** Generally the smaller the cell:
(a) The larger the nucleus
(b) The smaller the nucleus
(c) It will be metabolically more active
(d) It will be metabolically less active

223. Latest model that is proposed to explain the structure of plasma membrane:
(a) Molecular model
(b) Unit membrane model
(c) Fluid mosaic model
(d) None of these

224. An example of cell lacking nuclear membrane and mitochondria is:
(a) Protozoan cell
(b) Bacterial cell
(c) Algal cell
(d) Fungal cell

225. The peptidoglycan polymer forms the wall of:
(a) Fungi
(b) Prokaryotes
(c) Eukaryotes
(d) Higher plants

226. Cell membranes are composed mainly of: (MPPMT 2002)
(a) Starch and lipids
(b) Lipids and proteins
(c) Sugar and lipids
(d) Sugar and proteins

227. How the fibrils of cellulose are cemented together to form an elastic cell wall? They are cemented with the help of:
(a) Chitin (b) Pectin
(c) Lignin (d) Suberin

228. In an active protoplasm the largest quantity is of:
(a) Glucose (b) Protein
(c) Water (d) None of these

229. The conversion of plasmasol to plasmagel is:
(a) Physical phenomenon
(b) Chemical phenomenon
(c) Physico-chemical phenomenon
(d) Biochemical phenomenon

230. pH of cytoplasm is:
(a) Acidic (b) Alkaline
(c) Slightly acidic (d) Strongly basic

231. Chief organic substance present in cytoplasm is:
(a) Protein (b) Sugar
(c) Lipid (d) None of these

232. The highest percentage of cytoplasm is of:
(a) Oxygen (b) Carbon
(c) Hydrogen (d) Nitrogen

233. The main difference between animal and plant cell is:
(a) Plant cells lack rigid cell wall
(b) Animal cells lack rigid cell wall
(c) Plant cells possess small vacuoles
(d) Animal cells possess large vacuoles

234. A plant cell usually differs from an animal cell in the absence of:
(a) Ribosomes (b) Centriole
(c) Mitochondria (d) Endoplasmic reticulum

235. Who proposed that cell is a unit of life?
(a) Schleiden (b) Robert Hooke
(c) Malpighi (d) None of these

236. The ratio of lipid : protein in biological membranes is:
(a) 0.5 : 2 (b) 1 : 0.5
(c) 1 : 1.2 (d) 2 : 1

237. Basic living substance of all the cells is a viscous protoplasm. This theory was given by:
(a) Dujardin (b) Von Mohl
(c) Max Schultz (d) Purkinje

238. Membranes are mostly formed of:
(a) Fats and carbohydrates
(b) Carbohydrates and nucleic acids
(c) Proteins and nucleic acids
(d) Proteins and fats

239. The pits are formed in the layer:
(a) Middle lamella
(b) Secondary and tertiary walls
(c) Primary wall
(d) All of the above

240. The outermost layer of plant cell is:
(a) Cell wall (b) Cell membrane
(c) Cuticle (d) None of these

241. The chemical substance most abundantly present in the middle lamella is:
(a) Pectin (b) Lignin
(c) Suberin (d) Cutin

242. Continuity of cytoplasm from cell to cell is maintained through:
(a) Middle lamella (b) Plasmodesmata
(c) Endoplasmic reticulum (d) Cell membrane system

243. Where the secondary and the tertiary wall of material is deposited in a cell?
(a) In between middle lamella and primary wall
(b) Outside the primary wall
(c) Inside the primary wall
(d) Inside the tonoplast

244. Fruits soften on maturity due to:
(a) Conversion of starch into sugar
(b) Loss of pectate in middle lamella
(c) Incorporation of pectate in middle lamella
(d) Gel formation at acid pH

245. Mark the incorrect statement:
(a) All cells do not contain a true nucleus
(b) Respiration occurs in mitochondria
(c) Cell walls are generally made up of cellulose
(d) All living plant cells contain chlorophyll

*246. Hardness in unripe fruits is due to the presence of:
(a) Middle lamella
(b) Lignified walls
(c) Tanin and bitter compounds
(d) Acid and carbohydrates

247. When the plant increases in length then the wall of plant cell grows:
(a) By apposition
(b) By intussusception
(c) By both methods
(d) By none of the above methods

248. Cell wall is:
(a) Permeable (b) Semipermeable
(c) Selectively permeable (d) Impermeable

249. The aqueous pores in the membrane through which water enters a cell have a size approximately:
(a) 1 nm (b) 2 nm
(c) 3 nm (d) 4 nm

250. Similar function in both animal and plant cells is performed by:
(a) Cell membrane (b) Centrosome
(c) Cell wall (d) Chloroplast

251. A dead cell is different from a living cell in:
(a) The absence of specific organization
(b) The absence of vital face
(c) The absence of surrounding environment
(d) The absence of motility

252. Cells of the aleurone sheath of monocot seed contain abundance of:
(a) Starch (b) Essential oils
(c) Protein (d) None of these

*253. The organelle performing similar function in both animal and plant cells is:
(a) Chloroplast (b) Ribosome
(c) Cell wall (d) Contractile vacuole

130. Ribophorins are:
(a) Lipoproteins (b) Phosphoproteins
(c) Phospholipids (d) Glycoproteins

131. Besides leucoplasts, starch grains can develop in:
(a) Chromoplast (b) Chloroplast
(c) Mitochondria (d) Lysosome

132. The main role of nucleolus in nucleus is:
(a) Organization of chromosomes
(b) DNA replication
(c) Ribosome formation
(d) Chromatid separation

133. Eukaryotic ribosome breaks into:
(a) 50S and 30S (b) 60S and 40S
(c) 60S and 50S (d) 40S and 40S

134. Hydrolases of lysosome function at:
(a) Basic pH (b) Acidic pH
(c) Neutral pH (d) Any pH

135. Cellulose and hemicellulose (components of cell wall) are synthesized by:
(a) Lysosomes (b) Microsomes
(c) ER (smooth) (d) Dictyosomes

136. Feulgen (basic fuchsin) reaction is the specific test for establishing the presence of:
(a) RNA (b) DNA
(c) Protein (d) Starch

137. Bordered pits are very common in:
(a) Monocots (b) Dicots
(c) Pteridophytes (d) Gymnosperms

138. The least proportion of which one is found in plasma membrane:
(a) Proteins (b) Carbohydrates
(c) Lipids (d) All are equal

139. Rough ER is well developed in cells involved in: **(CPMT 1993)**
(a) Protein synthesis (b) Lipid synthesis
(c) Secretory functions (d) Nucleotide synthesis

140. The karyotheca facilitates:
(a) Anaphasic separation of daughter chromosome
(b) Nucleocytoplasmic exchange of materials
(c) Organization of spindle
(d) Synapsis of homologous chromosomes at meiosis

141. Octamer of 4 types of histones wrapped by DNA thread is called:
(a) Centrosome (b) Synaptonemal complex
(c) Microsome (d) Nucleosome

142. A multinucleate cell in plants is called:
(a) Syncytium (b) Coenobium
(c) Thallus (d) Coenocyte

*143. Extensive polymorphism is shown by which?
(a) Lysosome (b) Dictyosome
(c) Chloroplast (d) Ribosome

144. Genome is:
(a) Diploid set of chromosomes in an organism
(b) Genes in a diploid cell
(c) Chromosomes in gamete
(d) Genes in haploid set

Leucoplast

145. Largest cell organelle is:
(a) Golgi bodies (b) Chromosomes
(c) Chloroplast (d) Mitochondria

146. Phospholipid molecules are:
(a) Acidic (b) Alkaline
(c) Amphoteric (d) Amphipathic

147. Xanthophyll is:
(a) Carrot coloured (b) Yellow coloured
(c) Red coloured (d) Colourless

148. Quantasome contains:
(a) 60 chlorophyll molecules
(b) 200 chlorophyll molecules
(c) 230 chlorophyll molecules
(d) 300 chlorophyll molecules

149. The enzymes of Krebs' cycle are present in:
(a) ER (b) Mitochondrial cristae
(c) Mitochondrial matrix (d) Lysosomes

*150. Single naked chromosome is present in:
(a) Eukaryotes (b) Bacteria
(c) Both (a) and (b) (d) None of these

151. Cyclosis can be best observed in:
(a) Onion peelings
(b) Staminal hair of *Tradescantia*
(c) Pith cells
(d) None of the above

152. Cell organelles are embedded in:
(a) Protoplasm (b) Cytoplasm
(c) Nucleolus (d) Karyoplasm

153. Primary Division of organisms into Akaryobionta and Karyobionta is based on:
(a) Ribosomes (b) Nucleus
(c) Plasma membrane (d) None of these

154. Nuclear membrane disappears in prophase to form:
(a) Matrix (b) ER vesicle
(c) Ribosomes (d) Nucleolus

155. Who established nucleus as an important biological entity?
(a) Hooke (b) Malpighi
(c) Robert Brown (d) N. Grew

156. Solar energy is converted into ATP in:
(a) Mitochondria (b) Chloroplart
(c) Ribosomes (d) Peroxisomes

157. A prokaryotic cell lacks:
(a) Nuclear membrane
(b) Nucleolus
(c) Membrane bound organelles
(d) All of the above

158. ATP formation in mitochondria takes place in:
(a) Matrix (b) Cristae
(c) Outer membrane (d) None of these

159. Mitochondrion without its outer membrane is called:
(a) Chondriome (b) Chondriole
(c) Mitoplast (d) Chondrioide

160. Cane sugar is made of:
(a) 2 Glucose molecules
(b) 2 Fructose molecules
(c) One glucose and one fructose molecule
(d) Chain of glucose molecules

161. Fan-like crystals of inulin are present in roots of:
(a) Sugar beet (b) Artichoke
(c) *Dahlia* (d) None of these

162. Starch of potato is made of:
(a) Amylose (b) Amylopectin
(c) Both (a) and (b) (d) None of these

163. Eccentric starch grains are present in:
(a) Wheat (b) Maize
(c) Pea (d) Potato

164. Compound starch grains are found in:
(a) Wheat (b) Maize
(c) Banana (d) None of these

165. Which of the following liberates maximum energy on oxidation:
(a) Glucose (b) Fructose
(c) Proteins (d) Lipids

166. Amino acids in proteins are linked together by means of:
(a) H-bond (b) Phosphodiester bond
(c) Peptide bond (d) Ionic bond

167. Cytochromes, which are carriers of electrons contain which element?
(a) Co (b) Zn
(c) Mg (d) Fe

168. Oxidation of proteins gives a bad smell; this process is called:
(a) Denaturation (b) Decay
(c) Decomposition (d) Putrefaction

169. Chemistry of enzymes was first studied by:
(a) Fischer (b) Berzelius
(c) Kuhne (d) Sumner

170. 'Nectar' consists of:
(a) Glucose, fructose, galactose
(b) Glucose and fructose
(c) Sucrose, glucose and fructose
(d) None of the above

171. An excretory product, alkaloids, are present in:
(a) Cell vacuoles
(b) Cytoplasm
(c) Nucleus
(d) Both cell vacuole and cytoplasm

172. 'Hing' of commerce is a:
(a) Tannin (b) Resin
(c) Gum (d) Latex

173. Spherical structures called 'Druses' are present in:
(a) *Ficus* (b) Balsam
(c) *Eichhornia* (d) Papaya

174. Tartaric acid is present in:
(a) *Tamarindus* (b) *Citrus*
(c) *Oxalis* (d) None of these

175. Papain enzyme used in digestion of proteins is found in:
(a) Latex of Rubber (b) Latex of *Atropa*
(c) Resin of *Asafoetida* (d) Latex of Papaya

176. 'Key-lock theory' of enzyme action was given by:
(a) Michaelis (b) Mortan
(c) Sumner (d) Fischer

177. The general size of nucleus is:
(a) 0.5–5.0 μ (b) 5–30 μ
(c) 1–2 μ (d) None of these

178. Which one of the following is known as 'Store house of RNA'?
(a) Nucleus (b) Chromosome
(c) Nucleolus (d) None of these

179. In which largest chromosomes are present?
(a) Fungi (b) Wheat
(c) Trillium (d) Man

180. Heterosomes are chromosomes, which control:
(a) Somatic characters (b) Sex
(c) Both (a) and (b) (d) None of these

*181. Angular deviation in chromosomes is at:
(a) Primary constriction (b) Secondary constriction
(c) Both (a) and (b) (d) None of these

182. One picogram of DNA is the weight of:
(a) 20 cm DNA (b) 21 cm DNA
(c) 31 cm DNA (d) 41 cm DNA

183. Which one of the following are histones?
(a) $H_1A, H_2B, H_2, H_3, H_4$ (b) $H_1, H_2, H_3A, H_3B, H_4$
(c) $H_1, H_2A, H_2B, H_3, H_4$ (d) H_1, H_2, H_3, H_4, H_5

184. The diameter of nucleosome is:
(a) 1 nm (b) 12.5 nm
(c) 11 nm (d) 2 nm

185. Core particles are connected by:
(a) Nucleosomes (b) Chromomeres
(c) Linker DNA (d) None of these

186. Polytene chromosomes are found in: **(MPPMT 2002)**
(a) Oocyte nuclei of *Drosophila*
(b) Salivary gland cells of *Drosophila*
(c) Spermatocyte nuclei of *Drosophila*
(d) None of the above

187. The loops of Lampbrush chromosomes are made of:
(a) DNA only (b) RNA only
(c) DNA and proteins (d) DNA, RNA and proteins

188. Balbiani puffs are present in: **(CET Karnataka 2002)**
(a) Lampbrush chromosome (b) Polytene chromosome
(c) Both (a) and (b) (d) None of these

189. At anaphase, which of the following chromosomes attain 'I'-shape?
(a) Metacentric (b) Submetacentric
(c) Acrocentric (d) None of these

190. The first enzyme which was isolated in pure crystalline form is:
(a) Diastase (b) Pepsin
(c) Trypsin (d) Urease

191. The enzyme was first crystallized by:
(a) J. Northcrop (b) J.B. Sumner
(c) Buchner (d) Pasteur

*192. When the cofactor of an enzyme is an organic molecule, it is called:
(a) Apoenzyme (b) Holoenzyme
(c) Coenzyme (d) None of these

193. The catalytically active enzyme cofactor complex is called the:
(a) Coenzyme (b) Holoenzyme
(c) Apoenzyme (d) None of these

194. Hydrolysis of proteins is more efficiently catalyzed by:
(a) Sulphuric acid (b) HNO_3
(c) Diastase enzyme (d) None of these

*254. Plasma membrane particularly in animal cells is elastic due to:
(a) Carbohydrates (b) Lipids
(c) Proteins (d) Nucleotides

255. For the transport of ions, Protein-Lecithin theory (phosphatidic cycle) was given by:
(a) Lundegardh (b) Bennet Clarke
(c) Davson and Danielli (d) Robertson

256. Plasma membrane:
(a) Controls the passage of water and soluble substances in and out of the cell
(b) Helps in protein synthesis
(c) Serves as a semipermeable membrane
(d) None of the above

257. Major part of cell membrane is:
(a) Lipid (b) Protein
(c) Carbohydrates (d) Nucleic acid

258. The outermost membrane enclosing the contents of a plant cell is called:
(a) Tonoplast (b) Endoplasmic reticulum
(c) Plasmalemma (d) Cell wall

259. Fluid Mosaic model assumes that the:
(a) Bilayers of lipids and proteins are embedded inside
(b) Bilayers of lipids and proteins are floating on its either face
(c) Monolayer of lipid
(d) Bilayer of lipid is floating over proteins

260. The cell wall is made up of cellulose which is a:
(a) Liquid (b) Protein
(c) Amino acid (d) Polysaccharide

261. Torus is present in:
(a) Bordered pit (b) Simple pit
(c) Blind pit (d) None of these

262. In date palm seed coat is made up of:
(a) Lignin (b) Pectin
(c) Cellulose (d) Hemicellulose

263. Which of the following is not true? (CBSE 1990)
(a) Animal cells do not possess plastid
(b) Plant cells have large vacuole
(c) Plant cells have cellulosic wall
(d) Plant cells have plasmalemma unlike animal cell

264. The important part of glycoprotein is: (CBSE 1990)
(a) Protein (b) Carbohydrate
(c) Both (a) and (b) (d) None of these

*265. Sialic acid is present in:
(a) Chromatids (b) Golgi bodies
(c) Cell wall (d) Cell membrane

266. Plasmalemma functions as:
(a) An active interface
(b) A site for membrane receptor
(c) A limiting membrane
(d) Any or all of the above

267. The thickness of lipid zone of cell membrane is:
(a) 20 Å (b) 30–35 Å
(c) 70–80 Å (d) 80–90 Å

268. Ribosomes are the site for: (BHU 1992; MPPMT 1995)
(a) Photosynthesis (b) Protein synthesis
(c) Respiration (d) Fat synthesis

269. In the middle lamella of plant cell walls, one of the main elements is: (MPPMT 1995)
(a) Iron (b) Calcium
(c) Magnesium (d) Potassium

270. Which of the following structures controls the transport of the material into and out of living cells?
(a) Centrosome (b) Cell membrane
(c) Cell wall (d) Ribosome

271. Food is converted to energy in:
(a) Nucleus (b) Nucleolus
(c) Mitochondria (d) Chloroplast

272. Besides nucleus DNA is also present in:
(a) Ribosome (b) Mitochondria
(c) Lysosome (d) Golgi bodies

273. Cell membrane consists of:
(a) Proteins
(b) Phospholipids
(c) Both proteins and phospholipids
(d) Cellulose

274. All are membrane bounded cell organelles except:
(a) Sphaerosomes (b) Mitochondria
(c) Ribosomes (d) Lysosomes

275. The total thickness of unit membrane fall in the range of:
(a) 7–10 Å (b) 70–100 Å
(c) 700–1000 Å (d) 7,000–10,000 Å

276. Cell organelle found only in plants is:
(a) Mitochondria (b) Golgi complex
(c) Ribosomes (d) Plastids

277. Prokaryota means:
(a) A cell with many nuclei
(b) A cell without chloroplast
(c) A cell with diffused nucleus
(d) A cell with one nucleus

278. In a cell energy in the form of ATP is formed in:
(a) Lysosomes (b) Mitochondria
(c) Cytoplasm (d) Ribosomes

279. Centromere is concerned with:
(a) Splitting of chromosomes
(b) Formation of spindle fibre
(c) Movement of chromosomes to poles
(d) Duplication of DNA

280. Nucleic acids are found in:
(a) Cytoplasm
(b) Nucleus
(c) Both cytoplasm and nucleus
(d) Nucleus and ribosomes

281. In DNA the sugar is:
(a) Deoxyribose (b) Ribose
(c) Xylulose (d) Arabinose

282. Plasma gel refers to:
(a) Ectoplasm (b) Endoplasm
(c) Protoplasm (d) None of these

283. Carbohydrates are present in the plasmalemma in the form of:
(a) Starch (b) Cellulose
(c) Hemicellulose (d) Glycolipids

*284. If we separate the cell organelles of a living cell what part should be alive?
(a) Ribosome (b) Endoplasmic reticulum
(c) Cell wall (d) Chloroplast

285. Water which is an essential part of protoplast may constitute:
(a) Upto a quarter of it
(b) Upto half of it
(c) Upto three quarters of it
(d) More than three quarter of it

286. Tonoplast is a differentially permeable membrane surrounding the: (Raj. PMT 1990)
(a) Mitochondria (b) Cytoplasm
(c) Vacuole (d) Nucleus

287. Every living cell has a:
(a) Membrane (b) Food vacuole
(c) Chloroplast (d) Cell wall

288. Unit membrane (or plasma membrane) is made of:
(a) Cellulose (b) Lipoproteins
(c) Phosphoproteins (d) Phospholipids

289. Most of the water in mature plant cells occurs chiefly:
(a) In the nucleus (b) In the vacuoles
(c) In the cell walls (d) In the cytoplasm

290. The basis of grouping of living organisms into eukaryotes and prokaryotes is:
(a) Plasma membrane (b) Ribosomes
(c) Nucleus (d) None of these

291. Beet root does not lose colour. This is because:
(a) Plasma membrane is permeable
(b) Plasma membrane is impermeable
(c) Plasma membrane and cell wall are impermeable
(d) Both plasma membrane and cell wall are permeable

292. According to the mosaic model (proposed by Singer and Nicholson) plasma membrane is composed by:
(a) Phospholipids and integrate proteins
(b) Phospholipids, extrinsic proteins, intrinsic proteins
(c) Phospholipids, hemicellulose
(d) Cellulose, hemicellulose

293. Which of the following represents the correct sequence of the relative size in descending order:
(a) Chromosome, cell, nucleus, water molecule, oxygen atom
(b) Cell, nucleus, chromosome, water molecule, oxygen atom
(c) Cell, nucleus, water molecule, oxygen atom, chromosome
(d) Nucleus, water molecule, cell, chromosome, oxygen atom

294. Basal bodies are associated with the development of:
(a) Cell plate (b) Cilia and flagella
(c) Kinetochore (d) Phragmoplast

295. The early cell originated due to progressive chemical synthesis. This theory was confirmed by:
(a) Khorana (b) Mendel
(c) Miller (d) Darwin

296. The cell sap is the:
(a) Living content of the cell
(b) Non-living content of the protoplasm
(c) Non-living content of the vacuole
(d) None of these

297. Cell organelle which has electron transport system is:
(a) Centriole (b) Nucleus
(c) Mitochondria (d) Nucleolus

298. Following are called the power houses of cell:
(a) Golgi bodies (b) Nucleoli
(c) Mitochondria (d) Chloroplast

299. Which of the following structures is present in mitochondria?
(a) Polysomes (b) Dictyosomes
(c) Quantasomes (d) Oxysomes

300. Which of the following is absent in prokaryotic cell?
(a) Cell wall (b) Chromatophore
(c) Cytoplasm (d) Mitochondria

301. If living cells similar to those found on earth were found on a planet where there was no oxygen, which cell organelle would most probably be absent?
(a) Chromosomes (b) Mitochondria
(c) Ribosome (d) Cell membrane

302. A prokaryotic cell is that which has:
(a) A primitive nucleus (b) A true nucleus
(c) Two nuclei (d) Four nuclei

303. Which of the following cell organelles is considered to be rich in oxidative enzymes?
(a) Lysosomes (b) Endoplasmic reticulum
(c) Golgi bodies (d) Mitochondria

304. The length of the mitochondria ranges in between:
(a) 3–5 μ (b) 5–10 μ
(c) 10–50 μ (d) 50–300 μ

305. Organelles rich in catabolic enzymes are:
(a) Mitochondria (b) Golgi bodies
(c) Lysosomes (d) None of these

306. The non-protoplasmic cell inclusions are:
(a) Lysosomes (b) Ribosomes
(c) Mitochondria (d) Cystoliths

307. In striated muscles the mitochondria were first of all observed by:
(a) Kollicker (b) De Bary
(c) Robert Hooke (d) None of these

308. In plant cell protoplasm theory was established by:
(a) Strasburger (b) Max Schultz
(c) Robert Brown (d) None of these

309. Which of the following is a prokaryote?
(a) *Agaricus* (b) *Salmonella*
(c) Green algae (d) Bacteriophage

310. Mitochondria are present in:
(a) Gymnosperm
(b) Aerobic organisms only
(c) Obligate anaerobes
(d) All aerobic and obligate anaerobic organisms

311. What is the energy currency of a cell? (AMU 1992)
(a) DNA (b) RNA
(c) ATP (d) Vitamin

312. Maximum number of mitochondria are reported in:
(a) Parenchyma cell (b) Collenchyma cell
(c) Meristematic cell (d) None of these

313. Which of the following is responsible for cytoplasmic male sterility in maize?
(a) Nucleus (b) Mitochondria
(c) Chloroplast (d) Golgi bodies

314. Within the cell the site of respiratory or oxidative phosphorylation is:
(a) Mitochondria (b) Nucleolus
(c) Golgi bodies (d) Ribosomes

315. The diameter of mitochondria is:
(a) 0.5–2.0 μ (b) 2.0–5.0 μ
(c) 5–20 μ (d) 500–1000 μ

316. Number of mitochondria in a cell is:
(a) 10 (b) 100
(c) 1000 (d) Variable

*317. If the contents of a leaf tissue are carefully fractioned, which of the fractionates could be called alive?
(a) Endoplasmic reticulum (b) Cell wall
(c) Ribosome (d) Mitochondrion

318. An ATP molecule contains:
(a) One ribonucleotide molecule
(b) One deoxyribonucleotide
(c) One peptide
(d) One phosphatidic acid molecule

319. Which of the following observations most strongly supports the view that mitochondria contain electron transport enzymes aggregated into compact association?
(a) A contractile protein capable of utilizing ATP has been obtained from mitochondria
(b) Mitochondria have a highly folded inner wall
(c) Disruption of mitochondria yields membrane fragments which are able to synthesize ATP
(d) Mitochondria in animal embryos have a tendency to concentrate in cells which are to become of locomotory structures

320. Mitochondria is absent in a cell:
(a) Having nucleus (b) Devoid of nucleus
(c) Having plastids (d) All of these

321. DNA is present in:
(a) Plastids (b) Mitochondria
(c) Kinetoplast (d) All of these

322. ATP is generated when electrons pass through:
(a) NADH$_2$ to quinone (b) Cyt-c to Cyt-a
(c) Cyt-a to Cyt-a$_3$ (d) Cyt-a to Cyt-c

*323. In a mitochondrion the electron receptor is:
(a) Cytochrome-a (b) Cytochrome oxidase
(c) Water (d) Oxygen

324. Which of the following structures is present in mitochondria? (Raj. PMT 1992)
(a) Quantasomes (b) F$_1$ particle or Oxysome
(c) Dictyosome (d) Polysome

325. Lignin is mainly present in:
(a) Primary wall (b) Secondary wall
(c) Middle lamella (d) Plasmalemma

326. ATP, the energy currency of cell is synthesized in:
(a) Ribosome (b) Golgi complex
(c) Mitochondria (d) Nucleus

*327. In prokaryotic cell, the enzymes involved in the oxidation of metabolites are associated with:
(a) Nucleoid (b) Inner membrane
(c) Outer membrane (d) Ribosomes

328. Cristae are:
(a) Ingrowths of plasmalemma
(b) Ingrowths of thylakoids
(c) Ingrowths of the outer mitochondrial membrane
(d) Folds of the inner mitochondrial membrane

329. Mesosomes substitute the function of lysosome and mitochondria in:
(a) Protozoa and algae
(b) Bacteria and blue-green algae
(c) Mycoplasma and fungi
(d) None of the above

330. In which cell organelle the light energy is transformed into organic material: (Raj. PMT 1992)
(a) Chromoplast (b) Etioplast and leucoplast
(c) Chloroplast (d) Mitochondria

331. Plastid contains:
(a) Porous membrane (b) Cristae
(c) Thylakoids (d) Microtubules

332. In each granum there are:
(a) 2–50 thylakoids (b) 2–30 thylakoids
(c) 2–20 thylakoids (d) 2–100 thylakoids

333. From recent studies it has been found that pre-existing plastids arise from:
(a) Bodies called pro-plastids
(b) The nucleus
(c) The vacuole
(d) The cell wall

334. Light reaction takes place in:
(a) Grana (b) Stroma
(c) Thylakoids (d) Quantasomes

335. Chloroplast is:
(a) Completely dependent on nucleus
(b) Completely independent from nucleus
(c) Semi-autonomous body
(d) Autonomous body

336. Where respiratory organelle occurs in bacteria?
(a) Nucleus (b) Mitochondria
(c) ER (d) Mesosome

337. Photosynthetic units are:
(a) Microsomes (b) Sphaerosomes
(c) Glyoxysomes (d) Quantasomes

338. Photosystem-II (PS-II) is related to: **(CBSE 1992)**
(a) Grana
(b) Intergrana
(c) Stroma
(d) Outer membrane of the chloroplast

339. In a quantasome the number of chlorophyll molecules are:
(a) 130 (b) 230
(c) 250 (d) 330

340. Succinic dehydrogenase, aconitase and other enzymes of Krebs' cycle are present in:
(a) Inner membrane of mitochondria
(b) Matrix

(c) Perimitochondrial space
(d) Outer membrane of mitochondria

341. The semi-autonomous nature of mitochondria is because:
(a) It contains DNA, RNA and ribosomes
(b) It contains oxysomes
(c) It contains cristae
(d) It contains all of the above

342. The theory strongly advocating the morphological nature of protoplasm is:
(a) Granular theory of Altman
(b) Fibrical theory of Flemming
(c) Nuclear theory of Altman
(d) Colloidal theory of Wilson, Fischer and Hardy

343. ATP formation in mitochondria through electron transport chain is called:
(a) Oxidative phosphorylation
(b) Photolysis
(c) Photophosphorylation
(d) None of the above

344. The continuity of nucleoplasm and cytoplasm is maintained through nuclear pores in:
(a) Prokaryotic cells (b) Eukaryotic cells
(c) Both (a) and (b) (d) None of these

345. If you see mitochondria in an electron microscope, the distinguishing feature which you will observe is: **(Raj. PMT 1990)**
(a) Double membrane (b) Cisternae
(c) Cristae (d) Ribosome

*346. Cytochromes are present in:
(a) Mitochondria (b) Plasmalemma
(c) Golgi body (d) Nucleus

347. Plasmalemma possesses:
(a) Monolayer of lipid sandwiched between two layers of protein
(b) Bilayer of lipid sandwiched between two layers of protein
(c) Monolayer of protein between two layers of lipid
(d) Bilayer of protein between monolayers of lipid

348. In cell membrane which constituent is present in lesser proportion?
(a) Carbohydrate (b) Lipid
(c) Protein (d) Phosphorus

349. ATP formation takes place in mitochondria. This was discovered by:
(a) M. Calvin (b) Krebs and Lipmann
(c) Arnon (d) None of these

350. Size of the ribosome varies from:
(a) 100–150 Å (b) 150–250 Å
(c) 200–400 Å (d) 400–450 Å

*351. Cytogenes are present in:
(a) Ribosome (b) Nucleus
(c) Mitochondria (d) Protoplasm

352. Which of the following types of chloroplast are found in the cells of a higher plant? **(DPMT 1990)**
(a) Girdle-shaped (b) Star-shaped
(c) Discoidal (d) Reticulate

353. The size of mitochondrion ranges between:
(a) 1–5 μ (b) 5–10 μ
(c) 5–20 μ (d) 5–50 μ

354. One of the following shows endosymbiosis:
(a) Peroxisomes (b) Ribosomes
(c) Mitochondria (d) Centrioles

355. Which of the following plastids contains no granum and is called juvenile plastid?
(a) Chloroplast (b) Phaeoplast
(c) Rhodoplast (d) Etioplast

356. The enzyme present in stroma is:
(a) Catalase (b) Pyruvate carboxylase
(c) RuDP-Carboxylase (d) None of these

357. When a cell absorbs energy from an environment, the reaction is:
(a) ADP + AMP → ATP (b) ADP + PP → ATP + P
(c) ADP + P → ATP (d) ATP → ADP + P

358. Polygonal starch grains are found in: **(Raj. PMT 1991)**
(a) Wheat (b) Rice
(c) Pea (d) Maize

359. A chromosome with the centromere present in a diffused condition along its length is known as:
(a) Polycentric (b) Telocentric
(c) Acentric (d) Dicentric

360. Ribosomes attached to m-RNA form: **(EAMCET 1992)**
(a) Ribosomal complex (b) Protein ribosome complex
(c) Polyribosomes (d) None of these

361. In potato the starch grains are:
(a) Oval (b) Eccentric
(c) Concentric (d) Spherical

362. Hammerling performed an experiment on ***Acetabularia*** by exchanging: **(CBSE 1990)**
(a) Rhizoid and stalk (b) Gametes
(c) Nucleus (d) Cytoplasm

363. Polytene chromosomes were discovered for the first time in: **(CBSE 1995)**
(a) Chironomus (b) Fruit fly
(c) Housefly (d) None of these

364. In rapidly dividing cells, endoplamic reticulum is:
(a) Poorly developed (b) Highly developed
(c) Absent (d) Non-functional

365. Golgi apparatus is absent in: **(CBSE 1993)**
(a) Liver cells (b) R.B.C. (red blood cells)
(c) Blue-green algae (d) Higher plants

366. Pyrenoids are present in the chloroplasts of:
(a) An alga (b) Bryophyte
(c) Ferns (d) None of these

367. Which of the following organelle is not generally present in animal cell? **(MDAT Bihar 1991)**
(a) Plastid (b) Golgi complex
(c) Mitochondria (d) Endoplasmic reticulum

368. The genetic information is carried by long chain molecules of:
(a) Enzymes (b) Amino acids
(c) Nucleotides (d) Chromosomes

369. Phycoerythrin is present in:
(a) Chloroplast (b) Phaeoplast
(c) Rhodoplast (d) Leucoplast

370. The internal layer joining the primary wall of the two adjacent cells is called: (MPPMT 1994)
(a) Plasmodesmata (b) Middle lamella
(c) Casparian strip (d) Periderm

371. The 1992 Nobel Prize for medicine was awarded to Edmond Fischer and Edwin Krebs for their work on: (CBSE 1994)
(a) Human genome project
(b) Drug designing involving inhibition of DNA synthesis of the pathogen
(c) Regulation of cell processes due to reversible phosphorylation
(d) Isolation of gene

372. The inner envelope of chloroplast is impermeable to: (MPPMT 1990)
(a) Triose-1-phosphate (b) Orthophosphate
(c) Sucrose (d) Glutamine

373. The function of nucleolus is the synthesis of: (MPPMT 1994)
(a) t-RNA (b) m-RNA
(c) r-RNA (d) DNA

374. Site of formation of immature ribosomal subunits in a eukaryotic cell is:
(a) Cytoplasm (b) Nucleus
(c) Nucleolus (d) Nuclear pore complex

375. Middle lamella is composed of: (CPMT 1993)
(a) Lignin (b) Suberin
(c) Calcium pectate (d) Calcium phosphate

376. In prokaryotes which of the following is present? (MDAT Bihar 1995)
(a) Mitochondria (b) Nucleus
(c) Golgi body (d) None of these

377. In which of the following groups chromosomes are not organized?
(a) Prokaryotes (b) Algae
(c) Gymnosperms (d) Angiosperms

378. Nucleosomes are:
(a) Units of DNA (b) Units of RNA
(c) Units of protein (d) Units of chromosome

379. The strength and rigidity of a cell wall is due to the substance called: (MPPMT 1994)
(a) Suberin (b) Cellulose (c) Lignin (d) Pectin

380. The reaction occurring in the granum of chloroplast is:
(a) Hill reaction
(b) Blackman's reaction
(c) Synthesis of an enzyme
(d) Replication of the genophore

381. The eukaryotic chromosomes are made of: (MPPMT 1994)
(a) DNA and proteins (b) DNA and lipids
(c) DNA (d) RNA

382. Quantasomes are found in: (CPMT 1990)
(a) Mitochondria (b) Chloroplast
(c) Nucleus (d) Lysosome

383. Desmosomes are concerned with: (CBSE 1995)
(a) Cell division (b) Cellular excretion
(c) Cytolysis (d) Cell adherence

384. Plant cell differs from animal cell in: (AFMC 1993)
(a) Cell wall absent and chloroplast present in animal cell
(b) Cell wall present and chloroplast present in plant cell
(c) Cell wall present and chloroplast absent in plant cell
(d) Cell wall absent and chloroplast present in plant cell

385. Phragmoplast is the precursor of: (MPPMT 1994)
(a) Cell plate (b) Chromoplast
(c) Chloroplast (d) Colourless plastid

386. After germination, a seed did not develop green colour. This could be due to the deficiency of:
(a) Nitrogen (b) Fe
(c) Mg (d) Light

387. Structures for storage of starch, pigments, etc., are:
(a) Golgi bodies (b) Nucleus
(c) Plastids (d) Ribosomes

388. Which of the following is the marker enzyme of a plant dictyosome?
(a) Acid hydrolase
(b) Phospholipid synthetase
(c) Nucleoside diphosphatase
(d) Catalase

389. How many cisternae are present in a dictyosome?
(a) 3–12 (b) 13–15
(c) 16–19 (d) 1 to ∞

390. The cellular site of photophosphorylation is:
(a) Grana (b) Stroma
(c) Both (a) and (b) (d) None of these

391. Which of the following elements contributes to the formation of middle lamella? (CPMT 1990)
(a) Sodium (b) Iron
(c) Potassium (d) Calcium

*392. Sex chromosomes may be found in: (CPMT 1991)
(a) Unisexual flower (b) Unisexual plant
(c) Hermaphrodite plant (d) Monocarpic plant

393. Endoplasmic reticulum is absent in:
(a) Sieve cells (b) *E. coli*
(c) Mesophyll cells (d) All of these

394. When green tomatoes turn red then:
(a) Chromoplasts are changed to chloroplasts
(b) Chloroplasts are disintegrated and get converted into chromoplasts
(c) New chromoplasts are made
(d) None of the above

395. Dictyosomes are:
(a) A class of ribosome (b) A fibrillar organelle
(c) Respiratory particles (d) Golgi bodies

396. Which does not have DNA? (BHU 1991)
(a) Nucleus (b) Chloroplast
(c) Mitochondria (d) Ribosome

397. Lysosomes are rich in: (CBSE 1996)
(a) Carbohydrates (b) Hormones
(c) Nucleic acids (d) Hydrolytic enzymes

398. Which of the following is having a prokaryotic cell? (CBSE 1990)
(a) *Spirogyra* (b) *Amoeba*
(c) *Rhizopus* (d) *E. coli*

399. Oxygen is released by:
(a) Mitochondria (b) Ribosomes
(c) Chloroplasts (d) None of these

*400. Most plant cells are surrounded by cell wall. There are some exceptions, *e.g.*: (BHU 1990)
(a) Root hairs (b) Bacteria
(c) Stem hairs (d) Gametes

401. Organelle bound in triple membrane is:
(a) Transosomes (b) Lomasomes
(c) Plastids (d) None of these

402. Sedimentation coefficient in case of ribosomes of plastids is:
(a) 10S (b) 50S
(c) 70S (d) 80S

403. Maximum lysosomes occur in:
(a) Plant cells (b) Animal cells
(c) Both equally (d) Bacterial cells

404. Endoplasmic reticulum is a metabolic compartment. Which of the enzymes is specific for it?
(a) Phospholipid synthetase (b) Cellulase
(c) RuDP carboxylase (d) Cytochrome oxidase

405. The core of a chromosome is formed by:
(a) A linear strand of RNA
(b) A linear strand of DNA
(c) A super coiled core of DNA
(d) A super coiled core of RNA

406. During interphase the chromosomes which remain condensed are called:
(a) Allosome (b) Autosome
(c) Euchromosome (d) Mega chromosome

407. In Golgi bodies the space between cisternae is of:
(a) 30 Å (b) 130 Å
(c) 300 Å (d) 725 Å

408. The bacterial ribosomes are of:
(a) 50S type (b) 70S type
(c) 30S type (d) 80S type

409. An organelle shows a highly folded inner wall ultrasonic disruption or the organelle yields fragments which can synthesize ATP. The organelle is a: (CPMT 1990)
(a) Mitochondria (b) Ribosome
(c) Chloroplast (d) Centrosome

410. The chromosomes found during prolonged stage of mitotic prophase in the salivary glands of *Drosophila* are: (CPMT 1991)
(a) B-chromosomes (b) Lampbrush chromosomes
(c) Normal chromosomes (d) Polytene chromosomes

411. RNA serves an important role in: (CPMT 1991)
(a) Carbohydrate synthesis (b) Protein synthesis
(c) Fat synthesis (d) None of these

412. Chloroplast of a cell synthesizes:
(a) Carbohydrates (b) Fatty acids
(c) Hormones (d) All of these

413. Chromosomes consist of:
(a) DNA
(b) DNA + histone
(c) DNA + non-histone
(d) DNA + histone + non-histone

414. Puffs in the salivary gland chromosomes represent the site of:
(a) Protein synthesis (b) RNA synthesis
(c) DNA synthesis (d) DNA duplication

415. The endoplasmic reticulum often bears: (MPPMT 1994)
(a) Lysosomes (b) Centrioles
(c) Peroxisomes (d) Ribosomes

416. At what stage the chromosomes are more distinct and studiable?
(a) Interphase (b) Prophase
(c) Metaphase (d) Anaphase and telophase

417. Physical basis of heredity is:
(a) Nucleus (b) Nucleolus
(c) Nucleosome (d) Chromosomes

418. Differential staining of chromosome due to differential thickening is called:
(a) Epistasis (b) Hypostase
(c) Heteropycnosis (d) Heterochromosomes

419. Membranes occur in:
(a) Chromosomes, chloroplasts and starch grains
(b) Chromosomes, nuclei and mitochondria
(c) Cytoplasm, chloroplasts and mitochondria
(d) Cytoplasm, nuclei and starch grains

420. The endoskeleton of the cell is made up of:
(a) Mitochondria (b) Endoplasmic reticulum
(c) Cell wall (d) Cytoplasm

421. Endoplasmic reticulum is mainly concerned with:
(a) Fatty acid synthesis (b) Cholesterol synthesis
(c) Peptide bond formation (d) Proteolysis

422. Maximum polymorphism is exhibited by:
(a) Lysosomes (b) Ribosomes
(c) Golgi bodies (d) ER

423. What is the more plausible source for the origin of a single membrane bound structure?
(a) Nucleus (b) Cell wall
(c) ER (d) All of these

424. Lipid metabolism takes place in:
(a) Ribosome (b) Smooth ER
(c) Rough ER (d) None of these

425. Which of the following organelles is thought to be an artifact?
(a) Sphaerosome (b) Golgi body
(c) Centrosome (d) Lysosome

426. The Golgi complex originates from: (CPMT 1991)
(a) Cell membrane (b) Cytoplasm
(c) Mitochondria (d) Endoplasmic reticulum

*427. The organelle absent in intact cells is:
(a) Lomasomes (b) Ribosomes
(c) Microsomes (d) None of these

428. Mitochondria were discovered by:
(a) C. Benda (b) Altman
(c) Porter (d) Leeuwenhoek

429. If a ribosome is ribonucleoprotein particle, why should it not be RNA virus?
(a) Because it is non-replicative
(b) Because its protein is heterogeneous
(c) Because its RNA is diffused
(d) All of the above

430. Incubation of t-RNA from *E. coli* with m-RNA of mouse and ribosome of rabbit shall under appropriate conditions produce protein characteristic of:

(a) *E. coli* type (b) Mouse type
(c) Rabbit type (d) Mixed type

431. The organelle associated with the energy conversion reaction of aerobic respiration is:
(a) Chloroplast (b) Golgi body
(c) Nucleolus (d) Mitochondria

432. The main function of Golgi complex is:
(a) Translocation (b) Fermentation
(c) Glyco-oxidation (d) Phosphorylation

433. Golgi bodies are maximum in:
(a) Calyptrogen (b) Root cap
(c) Root tip (d) None of these

434. Lysosomes were discovered by: **(BHU 1991)**
(a) Porter (b) de Duve
(c) Golgi (d) Palade

435. The process occurring inside mitochondria is:
(a) Phosphorylation (b) Photorespiration
(c) Oxy-phosphorylation (d) None of these

436. Ribosome function upon:
(a) DNA (b) m-RNA
(c) t-RNA (d) Polypeptides

437. The minerals playing an important role in the maintenance of fluid balance in the cell are:
(a) Calcium and sodium (b) Iron and calcium
(c) Sodium and potassium (d) Potassium and calcium

438. Polyribosomes are the aggregation of:
(a) Several ribosomes held together by a string of m-RNA
(b) Ribosomes and r-RNA
(c) Only r-RNA
(d) Peroxisomes

***439.** The term protein body is used for:
(a) A ribosome
(b) An aleurone grain
(c) A protein crystal
(d) An ingested protein particle

440. Prokaryotic cell lacks:
(a) Endoplasmic reticulum, Golgi complex, mitochondria and lysosomes
(b) Chloroplast, cell membrane, DNA and RNA
(c) Lysosome flagella and DNA
(d) All of the above

441. Mitochondria actively participates in:
(a) Intracellular digestion (b) Cellular metabolism
(c) ATP hydrolysis (d) None of these

442. Ribosomes of bacteria, mitochondria and chloroplasts are of:
(a) 30S type (b) 50S type
(c) 70S type (d) 80S type

443. The non-living cell structure is:
(a) Centriole (b) Ribosome
(c) Dictyosome (d) Vacuole

444. The optically hyaline part of protoplasm is:
(a) Hyaloplasm (b) Endoplasm
(c) Cytoplasm (d) None of these

445. The digestive enzymes are present in the:
(a) Peroxisomes (b) Lysosomes
(c) Dictyosomes (d) Ribosomes

446. Yellowish tinge in the mitochondria is because of the presence of:
(a) Carotenes (b) Xanthophylls
(c) Anthocyanins (d) Riboflavin

447. Lysosomes are made up of:
(a) One membrane (b) Two membranes
(c) Three membranes (d) None of these

448. The protein synthesized over ribosomes is:
(a) Reserve food protein (b) Enzymatic protein
(c) Flagellar protein (d) All of these

449. Which of the following structures is the functional unit in a Golgi complex?
(a) Cristae (b) Cisternae
(c) Thylakoid (d) Archoplasm

450. The fragments of endoplasmic reticulum formed after homogenisation are:
(a) Peroxisomes (b) Glyoxysomes
(c) Microbodies (d) Microsomes

451. Colourless plastid storing starch is termed as:
(a) Elaioplast (b) Aleuroneplast
(c) Amyloplast (d) None of these

452. Urate oxidase occurs in:
(a) Lomasome (b) Peroxisome
(c) Mitochondria (d) Mesosome

453. Plasmodesmata help mainly in:
(a) Selective permeability
(b) Permits circulation of fluid and passage of solutes between the cells
(c) Helps in contraction
(d) None of the above

454. Organelle rich in hydrolytic enzyme is: **(CPMT 1993)**
(a) Dictyosomes (b) Lysosomes
(c) Mitochondria (d) Endoplasmic reticulum

455. The granular endoplasmic reticulum plays an important role in:
(a) Cell wall formation (b) Glycolysis
(c) Protein synthesis (d) None of these

456. Site of protein synthesis is:
(a) Ribosomes (b) Mitochondria
(c) Nucleus (d) DNA

457. Which characteristic enzymes are present in lysosomes?
(a) DNA polymerase (b) Ligase
(c) Acid hydrolase (d) Fatty acid synthase

458. In which cell organelle one type of organic material is converted into another type?
(a) Chloroplast (b) Etioplast
(c) Lysosome (d) Tubular ER

459. Ribosomal protein functions as:
(a) Structural proteins (b) Alkalies
(c) Lipids (d) Enzymes

460. The main constituents of protoplasm are:
(a) Oxygen, carbon, hydrogen and nitrogen
(b) Oxygen phosphorus and minerals
(c) Carbon, hydrogen and iron
(d) Iron, carbon, oxygen and nitrogen

461. Lysosomes do not help in: **(BHU 1993)**
(a) Ingestion of food
(b) Digestion of aged organelles

(c) Osmoregulation
(d) Destruction of cell during metamorphosis and development

462. Eukaryotic 80S breaks into:
(a) 40S and 40S (b) 60S and 40S
(c) 60S and 50S (d) 50S and 30S

463. The structure present outer to plasma membrane but inner to cell wall is:
(a) Sphaerosome (b) Lomasome
(c) Peroxisome (d) Dictyosome

464. Transfer of materials across the membrane takes place by:
(a) Passive transport (b) Active transport
(c) Both (a) and (b) (d) None of these

465. Double membrane is absent in:
(a) Nucleus (b) Lysosomes
(c) Mitochondria (d) Microsome

466. Ribosomes of mitochondria are of type:
(a) 30S (b) 50S
(c) 70S (d) 80S

467. In a eukaryotic cell the cytophorase system is located in:
(a) Cytoplasm (b) Nucleus
(c) Cristae (d) None of these

468. When 30S and 50S subunits of ribonucleoprotein unite together, the type of ribosome formed is:
(a) 70S (b) 80S
(c) 90S (d) 100S

469. How many different types of proteins are present in a ribosome of *E. coli.*?
(a) 24 (b) 34
(c) 55 (d) 74

*470. Prokaryotic ribosomes occur in:
(a) Prokaryotic cells (b) Eukaryotic cells
(c) Both (a) and (b) (d) None of these

471. Foldings of inner membrane of mitochondria are called:
(a) Cristae (b) Grana
(c) Calcium oxalate crystals (d) Sacs

472. Which plant cell possesses more dictyosomes or well developed Golgi complex?
(a) Digestive and secretory
(b) Secretory and meristematic
(c) Meristematic and Photosynthetic
(d) Photosynthetic and storage

473. Autophagic vacuole is:
(a) Vacuole filled with pigments
(b) A lysosome
(c) Lysosome containing engulfed subcellular particles
(d) None of the above

474. Most of the hydrolytic enzymes of lysosomes function at: (MPPMT 2002)
(a) Base pH (b) Acidic pH (pH 5)
(c) Neutral (d) Any pH

475. DNA is absent in one of the following:
(a) Nucleus (b) Mitochondria
(c) Peroxisomes (d) Chloroplast

476. Ribosomes are present in:
(a) Mitochondria only
(b) Nucleus only
(c) Nucleus, mitochondria and chloroplast
(d) Nucleus, mitochondria and centriole

477. The molecular weight of two RNA present in each ribosome is respectively:
(a) 7×10^6 and 7×10^6 daltons
(b) 1.8×10^6 and 2.2×10^6 daltons
(c) 1.6×10^6 and 0.7×10^6 daltons
(d) 1.6×10^6 and 0.2×10^6 daltons

478. Polyribosomes are composed of:
(a) Ribosomes and r-RNA
(b) Ribosomes and t-RNA
(c) Ribosomes and m-RNA
(d) Ribosomes and peroxisomes

479. What is the site of the synthesis of an RNA which goes to form a ribosome:
(a) ER (b) Cytosol
(c) Lysosome (d) Nucleolus

480. Oxidative phosphorylation occurs in:
(a) Dictyosome (b) Lysosome
(c) Chondriosome (d) None of these

481. Plasmid is: (CPMT 1993)
(a) Outgrowth of plasma membrane
(b) Part of ribosome
(c) Extranuclear DNA
(d) A plastid

482. The vacuoles in plant cells are derived from:
(a) Golgi complex (b) ER
(c) Lysosomes (d) None of these

483. Non-histone chromosomal proteins help in:
(a) Mutation
(b) Transcription and translation
(c) Translation and peptide synthesis
(d) Transcription and replication

484. The major portion of chromosome is composed of:
(a) Heterochromatin (b) Euchromatin
(c) Protein (d) None of these,

485. The ion, that maintains the structure of the two subunits of ribosome and hold the two subunits together is:
(a) Iron ion (b) Magnesium ion
(c) Metal ion (d) Magnesium

*486. Which of the following functions would stop first when the nucleus is removed from the mesophyll cell of a leaf?
(a) Phosphorylation
(b) Osmosis
(c) Photosynthesis
(d) Synthesis of cytoplasmic proteins

487. The shape of the chromosome is:
(a) Constant
(b) Changeable from phase to phase
(c) Changeable at every minute
(d) None of the above

488. Two amino acids are joined together in a polypeptide chain with the help of:
(a) Covalent bond (b) Peptide bond
(c) Electrovalent bond (d) Nuclear force

489. Which of the following maintain turgidity of the cell?
(a) Matrix in mitochondria (b) Cytoplasm
(c) Cell sap in the vacuole (d) None of these

490. The peroxisomes protect the cells from:
(a) High temperature
(b) High concentration of CO_2
(c) Low temperature
(d) Molecular O_2

*491. Cell organelle which mediate the biosynthesis of cutin and wax is:
(a) Ribosome (b) ER
(c) Sphaerosome (d) Centrosome

492. In prokaryotic cells the enzymes involved in the oxidation of metabolites are associated with:
(a) Nucleoid (b) Endoplasmic reticulum
(c) Ribosome (d) Plasma membrane

493. The discovery of nucleus was announced by an:
(a) American (b) Englishman
(c) Indian (d) Australian

494. Golgi ground substance lacks:
(a) Ribosomes and glycogen
(b) Ribosomes, glycogen and mitochondria
(c) Ribosomes, glycogen, mitochondria and chloroplast
(d) None of the above

*495. The colour of rose petals is due to the presence of water-soluble pigments in: (MPPMT 1994)
(a) Cytoplasm (b) Intercellular spaces
(c) Nucleus (d) Vacuoles

496. Dark bands of polytene chromosome take:
(a) Acidic stain (b) Basic stain
(c) Neutral stain (d) None of these

497. Centrosome is found in:
(a) Cytoplasm (b) Nucleus
(c) Chromosome (d) Nucleolus

498. The portion of cytoplasm in which centriole formation takes place is called:
(a) Centromere (b) Centrosome
(c) Desmosome (d) Microsome

499. Vesicles in Golgi bodies are found towards:
(a) *Cis*- face
(b) *Trans*- face
(c) Both *cis*- and *trans*- faces
(d) None of the above

500. Which of the following cell organelles protects the cell from the toxic effects of H_2O_2?
(a) Glyoxysomes (b) Peroxisomes
(c) Mitochondria (d) Centrosomes

501. Photorespiration occurs in:
(a) Chloroplast (b) Mitochondria
(c) Peroxisome (d) Glyoxysome

502. Growth by apposition in cell wall is usually:
(a) Centrifugal (b) Centripetal
(c) Radial (d) Zig-zag

503. Ergastic-matter in a cell includes:
(a) All living substances
(b) All non-living substance
(c) All the mitochondria present in a cell
(d) Plastidome in the cell

504. Folded-fibre model of chromatid was given by:
(a) Balbiani (b) Du Praw
(c) Hall (d) Sasaki

505. Besides giving out secretory vesicles the Golgi apparatus is also concerned with the formation of: (CBSE 1994)
(a) Grana of chloroplasts
(b) Cell plate after cell division in plants
(c) Lysosomes
(d) Plastids

506. Microsomes includes:
(a) Ribosomes
(b) Broken pieces of ER
(c) Ribosomes and broken pieces of ER
(d) None of the above

507. Each fibrillar unit is composed of:
(a) 5 microtubules (b) 6 microtubules
(c) 3 microtubules (d) None of these

508. Puffs (Balbiani rings) are associated with the synthesis of: (CBSE 1993)
(a) Starch (b) Fats and lipids
(c) Polysaccharides (d) m-RNA and proteins

509. Plasmodesmata commonly extend through:
(a) Intercellular spaces (b) Deplopore
(c) Intracellular spaces (d) Pits

*510. Which of the following chromosomes is a SAT-chromosome?
(a) Sex chromosome
(b) Nucleolus organizer chromosome
(c) Non-nucleolus organizer chromosome
(d) All of the above

511. Ribosomes are classified on the basis of:
(a) Type of r-RNA (b) Type of protein
(c) Position in the cell (d) Sedimentation coefficient

*512. The centriole consists of:
(a) 11 fibrillar units (b) 10 fibrillar units
(c) 9 fibrillar units (d) 7 fibrillar units

513. Which one of the following organelles is located near the nucleus and contains a collection of flattened membrane bound cisternae? (CBSE 1994)
(a) Golgi apparatus (b) Centriole
(c) Nucleolus (d) Mitochondria

514. The polytene structure of polytene chromosome was given by:
(a) Balbiani (b) DuPraw
(c) Hall (d) Sasaki

515. The cell sap is normally:
(a) Acidic
(b) Strong alkaline
(c) Slightly alkaline or neutral
(d) Neutral

516. The two main constituents of plasma membrane are: (CPMT 1993)
(a) Ca^{2+} and lipids
(b) Ca^{2+} and proteins
(c) Protein and carbohydrates
(d) Lipid and protein

517. The loops of lampbrush chromosomes are rich in:
(a) RNA only (b) DNA only
(c) RNA and proteins (d) Protein and DNA

518. The structure of nuclear membrane facilitates:
(a) Synapsis of homologus chromosomes at meiosis
(b) Nucleo-cytoplasmic exchange of materials
(c) Anaphasic separation of daughter chromosomes
(d) Organization of spindles

519. Protoplasmic streaming is performed by:
(a) Centrosome (b) Cilia
(c) Microtubules (d) None of these

*520. The cell recognition and adhesion in a cell is due to components of plasma membrane. These components are: (CBSE 1993)
(a) Protein molecules alone
(b) Lipid molecules alone
(c) Both protein and lipid molecules
(d) Glycoprotein and glycolipid

521. Chromosome theory of heredity states that:
(a) The genes are composed of chromosomes
(b) Chromosomes are composed of DNA + protein or the genes
(c) Every organism must possess chromosomes
(d) Chromosomes are universally present

522. Some metallic ions present in chloroplast are:
(a) Fe, Br, I and K (b) F, K, I and Fe
(c) Fe, Cu, Mn and Zn (d) Cu, K, I and P

523. Peroxisomes do not have:
(a) Urate oxidase and catalase
(b) Glycolate oxidase
(c) B-hydroxyacid oxidase
(d) d-amino acid oxidase

524. Part of cytoplasm which is optically homogeneous and forms continuous phase is called:
(a) Ectoplasm (b) Endoplasm
(c) Hyaloplasm (d) None of these

525. Number of chloroplasts per cell in higher plants are:
(a) 20–40 chloroplasts (b) 40–100 chloroplasts
(c) 30–70 chloroplasts (d) 20–90 chloroplasts

526. The chloroplasts of polyploid cells are comparatively:
(a) Larger than the chloroplasts of diploid cells
(b) Smaller than the normal diploid cells
(c) Do not show any change
(d) Chloroplast is deleted

527. Nucleolus was discovered by:
(a) Brown (b) Altman
(c) Benda (d) Fontana

528. What is a nucleolar organiser? (AIIMS 1990)
(a) Primary constriction (b) Secondary constriction
(c) Nucleolus (d) Nuclear matrix

529. Chlorophyll-a is characterised by the side group: (CBSE 1991)
(a) Methyl (b) Aldehyde
(c) Phytol (d) Ketone

530. In the nucleonema of nucleolus, particles 150 to 200 Å in diameter are seen which resembles:
(a) Mitochondria (b) Ribosomes
(c) Lysosome (d) Sphaerosomes

531. Intact chloroplasts can be isolated from green leaves by: (AIIMS 1990)
(a) Acetone (b) Ethanol
(c) Any alcohol (d) Sugar solution

532. The vehicle of heredity is the:
(a) Nucleus (b) Protoplasm
(c) Cytoplasm (d) Plastids

533. Cilia are produced by:
(a) Centrioles (b) Peroxisomes
(c) Dictyosomes (d) Golgi bodies

534. Instead of chromosomes, which of the following has only DNA?
(a) *Chlamydomonas* (b) *Volvox*
(c) *Anabaena* (d) *Plasmodiophora*

535. Nuclear ribosomes were discovered by:
(a) Palade and Claude (b) Svedberg
(c) Iso and Sato (d) R. Brown

536. Centriole lacks:
(a) DNA (b) RNA
(c) Plasma membrane (d) All of these

537. Which stage of eukaryotic cell is devoid of nuclear envelope?
(a) Interphase (b) Metabolic stage
(c) Metaphase (d) Telophase

538. Heterochromatin is genetically inert because:
(a) It contains small amount of DNA and large amount of RNA
(b) It contains large amount of DNA and small amount of RNA
(c) It contains large amount of DNA and RNA
(d) None of the above

539. Glyoxysomes perform:
(a) Hydrolysis (b) Lipolysis
(c) Proteolysis (d) None of these

540. Endomembrane system in the cell is composed of:
(a) Lysosomes (b) Vesicles
(c) Golgi bodies (d) Endoplasmic reticulum
(e) All of these

541. In prokaryotic cells, the enzymes involved in the oxidation of metabolites are associated with:
(a) Nucleoid (b) Plasma membrane
(c) ER (d) Ribosomes

542. The link between successive generations is provided by:
(a) Nucleus (b) Cytoplasm
(c) Thymins (d) Nucleic acid

543. Nucleoid is:
(a) A single inactive nucleus which is having double-stranded DNA and protein
(b) A group of chromosomes associated with proteins
(c) A nucleus without nuclear membrane and nucleolus
(d) A chromosome associated with proteins

544. Lysosomes are generally found in:
(a) Animal cells
(b) Plant cells
(c) Both animal and plant cells
(d) Bacterial cells

545. Site of formation of immature ribosomal units in a eukaryotic cell is: (CBSE 2002)
(a) Cytoplasm (b) Nucleus
(c) Nucleolus (d) Nuclear pore complex

546. The Golgi complex plays a major role: (BHU 1990)
   (a) As energy transducing organelle
   (b) In digesting proteins and carbohydrates
   (c) In trapping light quanta and transforming them into chemical energy
   (d) In glycosidation of lipids and proteins to produce glycolipids and glycoproteins

547. Chlorophyll can be compared to:
   (a) Blood of animals (b) Haemoglobin of animals
   (c) Protein of animals (d) None of these

548. Endoplasmic reticulum is absent in:
   (a) Bacteria (b) Ova
   (c) Embryonic cells (d) All of these

549. Minimum cell size that can be seen by light microscope is: (BHU 1993)
   (a) 1 μ (b) 0.5 μ
   (c) 0.25 μ (d) 0.1 μ

550. New mitochondria are formed:
   (a) From plasma membrane (b) By replication
   (c) From nuclear envelope (d) None of these

551. In which of the following groups the chromosomes are not organized?
   (a) Prokaryotes (b) Algae
   (c) Gymnosperms (d) Angiosperms

552. On the inner side of the nuclear envelope of many cells is present a fibrous material called:
   (a) Fibrous lamina (b) Internal dense lamella
   (c) Both (a) and (b) (d) None of these

553. Leucoplasts which store proteins are called:
   (a) Amyloplasts (b) Aleuroneplasts
   (c) Elaioplasts (d) Amyloplasts

554. Hammerling experimentally proved that nucleus was the physical basis of heridity on: (MPPMT 1990)
   (a) *Drosophila* (b) *E. coli*
   (c) *Acetabularia*. (d) *Neurospora*

555. Pinocytosis and phagocytosis are concerned with:
   (a) Cell wall (b) Plasmalemma
   (c) Nucleus (d) None of these

556. Desmosomes or tonofibrils are:
   (a) Subcellular particles
   (b) Another name of dictyosomes
   (c) Developed from plasmalemma at the point of cell contact
   (d) None of the above

557. Cytoplasm is a part of:
   (a) Cell wall (b) Protoplasm
   (c) Nucleus (d) Plastid

558. Cytochromes are:
   (a) H_2 acceptors (b) O_2 acceptors
   (c) Electron acceptors (d) Proton acceptors

559. The pores on nuclear membrane provide for:
   (a) Leakage of DNA into the cytoplasm
   (b) Leakage of nucleolus into the cytoplasm
   (c) Transport of macromolecules in and out of the nucleus
   (d) Transport of food materials into the nucleus for oxidation

560. Golgi apparatus is lacking in: (CBSE 1993)
   (a) Liver cells (b) Higher plants
   (c) Blue-green algae (d) Yeasts

561. The mitochondrial matrix contains:
   (a) Lipids, proteins, circular DNA molecules
   (b) 70S ribosomes and certain granules
   (c) Lipids and certain granules
   (d) Lipids, proteins and amino acids

*562. The two organelles responsible for cytoplasmic inheritance among eukaryotes are: (MPPMT 1993)
   (a) Lysosomes and mitochondria
   (b) Mitochondria and Golgi complex
   (c) Chloroplast and mitochondria
   (d) Chloroplast and lysosomes

563. Nucleocytoplasmic traffic through the nuclear pores is facilitated by: (CBSE 1990)
   (a) Protein nucleoplasmin (b) Protein rhodopsin
   (c) Nuclear lamina (d) Lipid bilayers

564. The different membrane systems of the cell which have a close structural and functional relationship are:
   (a) Golgi complex, ER and lysosomes
   (b) Golgi complex, cytochrome and lysosome
   (c) Polysomes, nucleus and ribosomes
   (d) None of the above

565. Mechanical support to the cell is given by:
   (a) Cilia (b) Lysosome
   (c) ER (d) Mitochondria

566. Nucleoids are present in all:
   (a) Plant cells
   (b) Animal cells
   (c) Bacterial cells and blue-green algae
   (d) None of the above

567. The mosaic model of plasma membrane can better explain permeability by:
   (a) Osmosis (b) Diffusion
   (c) Carrier process (d) Electrochemical gradient

568. The lampbrush chromosomes are visible with naked eyes at:
   (a) Metaphase-I (b) Metaphase-II
   (c) Leptotene (d) Diplotene

569. Liquid food drinking is:
   (a) Pinocytosis (b) Phagocytosis
   (c) Imbibition (d) None of these

570. The chromosome having centromere slightly away from the centre is:
   (a) Acentric (b) Telocentric
   (c) Submetacentric (d) Acrocentric

571. The structure of the nuclear membrane facilitates:
   (a) Organisation of the spindle
   (b) Synapsis of homologous chromosomes
   (c) Nucleo-cytoplasmic exchange of materials
   (d) Anaphasic separation of daughter chromosomes

572. The chromosome having centromere almost in the centre is:
   (a) Metacentric (b) Telocentric
   (c) Submetacentric (d) Acrocentric

573. The chief organic component of the cell is:
   (a) Water and sugar
   (b) Carbon dioxide and water
   (c) Lipid and vitamins
   (d) Proteins

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574. What shape is assumed by an acrocentric and telocentric chromosome at the anaphase of meiosis?
(a) I and V shape (b) V and J shape
(c) J and I shape (d) I and J shape

575. Nuclear membrane has originated from:
(a) Tonoplast (b) Plasma membrane
(c) Mitochondria (d) ER

576. On growing older the structure and function of cell and tissues of a plant deteriorates progressively; this process is known as:
(a) Senescence (b) Lytic
(c) Lysosome (d) Cellular changes

577. Chromosomes are important for:
(a) Variation
(b) Evolutionary development of species
(c) Mutation
(d) All of the above

578. Nucleoli are rich in:
(a) DNA and RNA
(b) DNA, RNA and proteins
(c) DNA
(d) RNA

579. Which of the following pairs of structures are related?
(a) Basal granules and ER
(b) Centrioles and nuclear reticulum
(c) Basal granule and centriole
(d) Nuclear reticulum and ER

580. Every living cell has a:
(a) Membrane (b) Food vacuole
(c) Chloroplast (d) Cell wall

581. Chromosome having a terminal centromere is called:
(a) Metacentric (b) Acrocentric
(c) Telocentric (d) Acentric

582. Brownian movement is an index of:
(a) Presence of crystals in protoplasm
(b) Colloidal nature of protoplasm
(c) pH variation of the protoplasm
(d) Abnormality of protoplasm

583. Chromosomes which do not participate in sex determination are called:
(a) Heterosomes (b) Autosomes
(c) Both (a) and (b) (d) None of these

584. In Singer-Nicholsön (1972) fluid mosaic model, extrinsic proteins are: (AMU 1991)
(a) Superficially arranged and can be separated easily
(b) Superficially arranged and cannot be separated easily
(c) Tightly attached to intrinsic proteins and cannot be separated easily
(d) Tightly attached to intrinsic proteins and can be separated easily

585. The basal granules or kinetosomes are found at the base of:
(a) Cilia (b) Flagella
(c) Both cilia and flagella (d) None of these

586. Cell wall formation starts with:
(a) The formation of middle lamella
(b) The formation of primary wall
(c) The formation of phragmoplast
(d) None of these

587. Glyoxysomes are concerned with the metabolism of: **(BHU 1993)**
(a) Proteins (b) Carbohydrates
(c) Fats (d) All of these

588. Centrioles are found in: **(Raj. PMT 1992; MPPMT 1994)**
(a) Centromere (b) Centrosome
(c) Chromosome (d) Spindle fibres

589. Prokaryote is a group of organisms which lack:
(a) Nuclear membrane and nucleolus
(b) 80S ribosome and centriole
(c) Chromosomal matrix
(d) All of the above

590. Nucleoproteins in a cell are synthesized in:
(a) Nucleolus (b) Nucleoplasm
(c) Nuclear membrane (d) Outside the nucleus

591. Chromosomes determining sex are called:
(a) Autosomes (b) Heterosomes
(c) Idiosomes (d) None of these

592. When a ripe tomato is pricked with a needle, a watery fluid comes out. This fluid is stored in:
(a) Cytoplasm (b) Plastid
(c) Vacuole (d) Nucleus

593. Protein essential for chromatin formation is:
(a) Actin (b) Tubulin
(c) Histone (d) Myosin

594. Lysosome is found in:
(a) A flagellum (b) Nucleus
(c) Cell (d) ER

595. The chromatin refers to which of the following areas in the electron micrograph of the interphase nucleus?
(a) The clear area
(b) The thread-like bodies
(c) The dark staining patches
(d) The outer membrane

596. Ergastic matter in a cell includes:
(a) All living substances
(b) All non-living substances
(c) All the mitochondria present in a cell
(d) Plastidome in the cell

597. Nuclei originate from pre-existing nuclei was first suggested by:
(a) Hofmeister (b) Strasburger
(c) Virchow (d) Hetwig and Van Benden

598. Growth by apposition in cell wall is usually:
(a) Centrifugal (b) Centripetal
(c) Radial (d) Zig-zag

599. Diameter of nucleopore is:
(a) 100-200 Å (b) 400–800 Å
(c) 700–1000 Å (d) 50–5000 Å

600. Mitochondrial matrix is:
(a) Homogeneous (b) Heterogeneous
(c) Alveolar (d) Fibrillar

601. Centriole is situated near the nucleus because it is an integral part of:
(a) Kinetosome (b) Nucleolus
(c) Kinetochore (d) Neuromotor apparatus

602. In both eukaryotic and prokaryotic cells, the organelle common is:
(a) Microtubules
(b) Microbodies
(c) Microfilaments
(d) Ribosomes

603. A chromatid is:
(a) Gene
(b) One-half of a chromosome
(c) Complete set of chromosomes
(d) None of the above

604. Centrosome occurs in:
(a) All plants
(b) All animals
(c) All plants and a few animals
(d) All animals and a few lower plants

605. For ion transport the cytochrome pump theory was given by:
(a) Bennet Clark
(b) Lundergardh
(c) Huxley
(d) None of these

606. Lysosome containing plant cell is:
(a) *Acetabularia*
(b) *Riccia*
(c) *Neurospora*
(d) None of these

607. The colour of chromoplast is: (CPMT 1992)
(a) Red
(b) Yellow
(c) Orange
(d) All of these

608. The functions of peroxisomes are:
(a) Synthesis of glycine
(b) Synthesis of serine
(c) Protection of cellular organelles from the toxic effect of H_2O_2
(d) All of the above

609. Middle lamella is a part of: (BHU 1991)
(a) Cell wall
(b) Nucleoplasm
(c) Middle lamella
(d) Pfasmalemma

610. Three kinds of structures forming endoplasmic reticulum are:
(a) Smooth and tubules
(b) Cisternae, vesicles and tubules
(c) Angular, granular and tubules
(d) Cisternae, angular vesicles

611. The chemical substance in the cork cell wall is:
(a) Lignin
(b) Cutin
(c) Chitin
(d) Suberin

612. The percentage of water in a typical plant cell is:
(a) 10%
(b) 30%
(c) 50%
(d) 85%

613. F_1 particles are present in:
(a) Chloroplasts
(b) Mitochondria
(c) Dictyosomes
(d) Nucleus

614. The main difference between active and passive transport across cell membranes is that: (CBSE 1993)
(a) Active transport occurs more rapidly than passive transport
(b) Passive transport is non-selective
(c) Passive transport requires a concentration gradient across the cell membrane whereas active transport requires metabolic energy
(d) Passive transport is confined to anions and active transport is for cations only

615. The number of chromosomes are constant for a particular species was stated by:
(a) W. Waldeyer
(b) Morgan
(c) Bateson and Punnett
(d) Benden and Boveri

616. Centromere is a part of: (BHU 1991)
(a) Ribosome
(b) Chromosome
(c) Mitochondria
(d) ER

617. Chromosomes bearing satellites are called SAT-chromosomes. The prefix SAT stands for:
(a) Same All Thymonuclenico
(b) Sine Acid Thymonucleinico
(c) Sine Acid Thy
(d) SATellite acid

618. Another name of kinetochore or centromere is:
(a) Primary constriction
(b) Secondary constriction
(c) SAT region
(d) Nucleolus organizer

619. The nucleolus has developed relatively late in evolution, so many lower species lack this structue such as:
(a) Yeast
(b) Bacteria
(c) Some algae
(d) All of these

620. First of all peroxisomes were reported from:
(a) Nerve cell
(b) Liver cell
(c) Kidney cell
(d) None of these

621. Which of the following functions are assigned to microtubules?
(a) Transport of nucleic acid
(b) Transport of m-RNA from nucleus to cytoplasm
(c) Transport of polysaccharides from Golgi apparatus to the cell wall
(d) All of the above

622. The main function of Golgi complex is:
(a) Translocation
(b) Fermentation
(c) Glycosidation
(d) Phosphorylation

623. Euchromatin is: (Raj. PMT 1991)
(a) Less active darkly staining region of the chromatin
(b) Less active lightly staining region of the chromatin
(c) More active darkly staining region of the chromosome
(d) More active weakly staining region of the chromatin

624. Fastest known enzyme is:
(a) Ribozyme
(b) Lysozyme
(c) Carbonic anhydrase
(d) RuBisco

625. The term heterochromatin was given by:
(a) Emil Heitz
(b) Darlington
(c) Morgan
(d) Hammerling

626. Which of the following will comprise the most appropriate distinction of prokaryotic cells to distinguish them from eukaryotic cells? (CPMT 1990, 91)
(a) Lack of DNA and nuclei
(b) Having dispersed DNA without a bounding nuclear membrane and by their lack of membrane bound organelles like plastids and mitochondria
(c) Lack of ribosomes
(d) Biochemistry being fundamentally different

627. Which of the following is a non-reducing sugar?
(a) Glucose
(b) Maltose
(c) Starch
(d) Lactose

628. Lysosomes are so called because they contain enzymes which are: (MPPMT 1994)
(a) Carboxylating (b) Respiratory
(c) Oxidizing (d) Digestive

629. Genophore is the name of: (CBSE 1993)
(a) Circular DNA
(b) Bacterial DNA
(c) Single double stranded DNA
(d) None of the above

630. Autolysis is associated with: (DPMT 2003)
(a) Centrosome (b) Sphaerosomes
(c) Lysosomes (d) None of these

631. Glyoxylate cycle plays an important role in the conversion of:
(a) Glycerol into carbohydrates
(b) Simple carbohydrates into complex carbohydrates
(c) Fatty acid into carbohydrates
(d) Proteins into carbohydrates

632. Chromosomes are made up of:
(a) DNA (b) RNA
(c) Proteins (d) DNA, RNA and proteins

633. Which of the following is widely distributed in a cell?
(a) DNA (b) RNA
(c) Chloroplast (d) Chromoplast

634. Cellulose and hemicellulose which are constituents of cell wall are synthesized by:
(a) Lysosomes (b) Microbodies
(c) Smooth ER (d) Golgi apparatus

635. Chloroplast is: (BHU 1993)
(a) Completely independent from nucleus
(b) Completely dependent upon nucleus
(c) Semi-autonomous body
(d) Autonomous body

636. Which type of enzyme inhibition can be overcome by increasing concentration of substrate molecules?
(a) Denaturation
(b) Competitive inhibition
(c) Non-competitive inhibition
(d) Feedback inhibition

637. The basic substance of nucleus is:
(a) Sugar (b) Amino acid
(c) DNA (d) Fats

638. Mitochondria are believed to be bacterial endosymbionts of cells because: (CET J & K 2002)
(a) They have their own nucleic acid
(b) Their membrane resembles those of bacterium
(c) These do not arise *de novo*
(d) They have all of the above attributes

639. An undifferentiated fibrillar or diffused nucleus is the characteristics of:
(a) Eukaryotic cell (b) Prokaryotic cell
(c) Cell of higher organisms (d) Cell of higher animals

640. Chromosomes determining sex are called:
(a) Oxysomes (b) Autosomes
(c) Heterosomes (d) None of these

641. Protoplasm present inside the nucleus is known as:
(a) Nucleoplasm (b) Amyloplast
(c) Elaioplast (d) Cytoplasm

642. Core of the nucleosome is made up of: (CBSE 1993)
(a) DNA
(b) Non-histones
(c) H_2A, H_2B, H_3, H_4, Histones
(d) Histones, H_2A, H_2B, H_3A, H_3B and H_4

643. Single microtubules have a diameter of:
(a) 100 Å (b) 150 Å
(c) 200 Å (d) 240 Å

644. Outermost layer of cell wall is:
(a) Middle lamella (b) Plasmalemma
(c) Primary wall (d) Secondary wall

645. Nucleo-cytoplasmic flux of material through the nuclear pore is facilitated by: (CBSE 1992)
(a) DNA and nucleoplasm in proteins
(b) Nuclear membrane
(c) Pore proteins
(d) Cytoplasmic proteins

646. *Saccharomyces cerevisiae* (yeast) is:
(a) Akaryote (b) Prokaryote
(c) Mesokaryote (d) Eukaryote

647. The most abundant protein in the plant world is found in:
(a) Root hairs (b) Mitochondria
(c) Chloroplasts (d) Virus

648. Who proposed the concept of unit membrane for tripartite structure of lipoproteins?
(a) Buvat (b) Robertson
(c) Davson and Danielli (d) None of these

649. Inulin crystals which is a carbohydrate are found in:
(a) Mango root (b) Wheat root
(c) Sugar cane root (d) Dahlia root

***650.** Cell organelle common in Protista and Monera is: (AMU 1991)
(a) Lysosome (b) Ribosome
(c) Chloroplast (d) Vacuoles

651. A macrofibril of cellulose is made up of:
(a) 5,000 molecules (b) 50,000 molecules
(c) 5,00,000 molecules (d) 1,00,000 molecules

652. Inner mitochondrial membrane contains enzymes called:
(a) NADH cytochrome reductase and monomeric oxidase
(b) Adenylatekinase and nucleoside diphosphokinase
(c) ATP-synthatase, succinic dehydrogenase and respiratory chain enzymes
(d) Malate and isocitrate dehydrogenase, fumarate, aconitase and citrate synthatase

653. Chemical nature of carrier molecules facilitating transport across plasma membrane is:
(a) Fatty acids (b) Sugary
(c) Starchy (d) Proteinaceous

654. The organelle which acts as a factory for the synthesis of sugars in autotrophic eukaryotes is: (AIIMS 1992)
(a) Mitochondria (b) Endoplasmic reticulum
(c) Chloroplast (d) Ribosome

655. Based on his own observation as well as those of others in 1838 Schwann made a tentative statement that all living things are made up of cells. When first suggested in 1838 this statement was:
(a) An assumption (b) A generalization
(c) An observation (d) A law

*656. The membrane bound enzyme involved in Krebs' cycle in mitochondria is: (AIIMS 1992)
(a) Fumerase (b) Malate dehydrogenase
(c) *Cis*-aconitase (d) Succinic dehydrogenase

657. The filaments associated with cilia and flagella are constituted by: (AIIMS 1992)
(a) Microtubules (b) Microfilaments
(c) Microfibrils (d) Microvilli

658. Smooth endoplasmic reticulum is well developed in the cells which synthesize:
(a) Steroids (b) Proteins
(c) Carbohydrates (d) All of these

659. The nucleosome concept favours the:
(a) Single strand model (b) Multiple strand model
(c) Double strand model (d) None of these

660. Leucoplast which stores oil is called:
(a) Amyloplast (b) Aleuroneplast
(c) Elaioplast (d) None of these

661. Which is not a mechanical cell organelle?
(a) Sphaerosome (b) Centrosome
(c) Cilia and flagella (d) Microtubules

662. In some lysosomes, the inactive enzymes are present. These are called:
(a) Autophagosomes (b) Residual bodies
(c) Secondary lysosomes (d) Primary lysosomes

663. Stroma contains:
(a) Ribosomes
(b) Osmiophilic drops
(c) Ribosomes and osmiophilic drops both
(d) None of the above

664. In cells of higher plants, the organelle absent is:
(a) Plasma membrane (b) Cell wall
(c) Ribosome (d) Centriole

665. Chromosomes were first observed by:
(a) Strasburger (b) Flemming
(c) Hofmeister (d) Nawaschin

666. Mitochondria have:
(a) DNA (b) RNA
(c) Both (a) and (b) (d) None of these

667. Microbodies include:
(a) Ribosomes
(b) Glyoxysomes
(c) Glyoxysomes, peroxisomes and lysosomes
(d) Lysosomes only

668. Which of the following theories is the most recent theory about the nature of cytoplasm?
(a) Reticulate theory (b) Alveolar theory
(c) Colloidal theory (d) Granular theory

*669. Protein tubulin does not occur in: (BHU 1993)
(a) Microtubules (b) Plasma membrane
(c) Flagella (d) Cilia

670. The peripheral layer of cytoplasm which is known as ectoplasm is:
(a) Non-granular (b) Viscous
(c) Clear (d) All of these

671. What happens to a cell if its nucleus is removed?
(a) The cell dies (b) Its catabolism increases
(c) Its metabolism decreases (d) It becomes non-osmotic

672. Cytoplasm has the property of:
(a) Asexual reproduction (b) Sexual reproduction
(c) Asexual and sexual both (d) None of these

673. Nucleoli are mainly formed by:
(a) Chromosomes (b) Chromatin
(c) DNA, RNA and proteins (d) RNA

674. A body formed when a proteinaceous granule is surrounded by starch is:
(a) Volutin (b) Pyrenoid
(c) Microsome (d) Dictyosome

675. The process which results in the formation of polytene chromosomes is:
(a) Meiosis (b) Amitosis
(c) Endomitosis (d) None of these

676. A living plant cell which is anucleated is:
(a) Vessel (b) Tracheid
(c) Sieve tube (d) None of these

677. The acrosome is formed by:
(a) Nucleus (b) ER
(c) Dictyosome (d) Mitochondria

678. The sedimentation of ribosome is measured by:
(a) Angstrom (Å) (b) Micron (μ)
(c) Svedberg (S) (d) None of these

679. A multinucleate cell is:
(a) Coenobium (b) Synchytrium
(c) Coenocyte (d) None of these

*680. All plastids have essentially the same structure because: **(CBSE 1992)**
(a) All plastids have to store starch, lipids and proteins
(b) They have to perform the same functions
(c) They are localised in the aerial part of the plant
(d) One type of plastid can differentiate into another type of plastid depending upon the cell requirement

681. Structure associated with cilia and flagella is:
(a) Desmosome
(b) Phragmosome
(c) Kinetoplast/Basal granule/Basal bodies
(d) Centromere

682. Which of the following has the highest percentage in a chromosome?
(a) DNA (b) RNA
(c) Basic proteins (d) Acidic proteins

683. Chromosomes which become decondensed during mitotic phase are called:
(a) Mega chromosome (b) Polytene chromosome
(c) Allosome (d) Autosome

684. Cellular recognition and adhesion are facilitated by components of plasma membranes. These components are generally: **(CBSE 1993)**
(a) Lipid molecule alone
(b) Protein molecule alone
(c) Both lipid and protein molecules
(d) Glycolipids and glycoproteins

685. Animal cells differ from plant cells in having: **(MPPMT 1995)**
(a) Centrosome (b) Golgi body
(c) Vacuole (d) Plastid

686. Site for cellular respiration is: (MDAT Bihar 1995)
(a) Nucleus (b) Ribosome
(c) Mitochondria (d) ER

687. Cystoliths sometimes deposited in plant cells are crystals of:
(a) $CaCO_3$ (b) $CaCl_2$
(c) Ca oxalate (d) Potassium bicarbonate

688. Which of the following pairs is not correctly matched? (MPPMT 1993)
(a) Cristae: The shelves formed by the folding of the inner membrane of mitochondria
(b) Plasmodesmata: The membrane surrounding the vacuoles in plants
(c) Grana: Membrane bound disc in chloroplasts that contain chlorophylls and carotenoids
(d) Middle lamella: Layers between adjacent cell walls in plants derived from cell plate

689. Rough endoplasmic reticulum differs from smooth-walled endoplasmic reticulum by one of the following statements: (CPMT 1996)
(a) Due to the presence of certain ergastic substance
(b) Due to the presence of ribosomes
(c) Due to the presence of nucleus
(d) Due to the presence of DNA

690. Fibrillar portion of nucleolus is composed of:
(a) Protein (b) Protein and RNA
(c) DNA (d) RNA only

691. Lysosomes are rich in: (CBSE 1996)
(a) Carbohydrates (b) Hormones
(c) Nucleic acids (d) Hydrolytic enzymes

692. Sphaerosomes are formed from:
(a) ER (b) Golgi bodies
(c) Nuclear membrane (d) Plasma membrane

693. Electron microscope has revealed the presence of: (AFMC 1996)
(a) Leucoplast (b) Chloroplast
(c) Chromosome (d) Ribosome

694. Which one of the following contains a hydrolytic enzyme? (CPMT 1996)
(a) Mitochondria (b) Lysosome
(c) Ribosome (d) Peroxysome

695. The outer layer of vacuole is called: (CPMT 1996)
(a) Tonoplast (b) Cell wall
(c) Plasmolayer (d) None of these

696. Controlling centre of cell is: (AFMC 1996)
(a) Nucleus (b) Nucleolus
(c) Mitochondria (d) Ribosome

697. What is the work of centrosome? (CPMT 1996)
(a) Cell wall formation (b) Cell plate formation
(c) Cell differentiation (d) Cell division

698. Cristae help in: (CPMT 1996)
(a) Respiration (b) Transpiration
(c) Photosynthesis (d) Photo-oxidation

699. Krebs' cycle is found in: (AFMC 1996)
(a) Anaerobic respiration (b) Photorespiration
(c) Photosynthesis (d) Aerobic respiration

700. Continuity of cytoplasm through cell to cell is controlled by:
(a) Plasmodesmata (b) Plasma membrane
(c) Cell membrane (d) Nucleolus

Match the following (Qs. 701–705)

701.

I. Purkinje	A. Protoplasm
II. Virchow	B. *Omnis cellula e cellula*
III. Robert Brown	C. Nucleus
IV. Schleiden and Schwann	D. Cell theory:

(a) I-A, II-B, III-C, IV-D (b) I-B, II-A, III-C, IV-D
(c) I-A, II-C, III-D, IV-B (d) I-D, II-C, III-A, IV-B

702.

I. Porter	A. Golgi bodies
II. C. de Duve	B. Ribosome
III. Palade	C. ER
IV. C. Golgi	D. Lysosomes:

(a) I-A, II-B, III-C, IV-D (b) I-C, II-D, III-B, IV-A
(c) I-D, II-C, III-A, IV-B (d) I-C, II-D, III-A, IV-B

703.

I. ER	A. Power house of cell
II. Cristae	B. Ergastoplasm
III. Mitochondria	C. Inner foldings of mitochondria
IV. Chromoplasts	D. Variously coloured plastids:

(a) I-B, II-C, III-A, IV-D (b) I-A, II-B, III-C, IV-D
(c) I-A, II-B, III-D, IV-C (d) I-D, II-A, III-C, IV-B

704.

I. Microtubules	A. Robertis and Franchi
II. Ribosomes in plants	B. Robinson and Brown
III. Nuclear pores	C. Prokaryotes
IV. Nucleoid	D. Callan and Tomlin:

(a) I-A, II-B, III-C, IV-D (b) I-A, II-B, III-D, IV-C
(c) I-B, II-A, III-C, IV-D (d) None of these

705.

I. Metacentric	A. Centomere at the centre of chromosome
II. Sub-metacentric	B. Centromere near end of chromosome
III. Acrocentric	C. Centromere at some distance from centre
IV. Telocentric	D. Centromere at the tip:

(a) I-A, II-B, III-C, IV-D (b) I-A, II-B, III-D, IV-C
(c) I-A, II-C, III-B, IV-D (d) I-A, II-D, III-C, IV-B

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706. Cell was discovered by: (AFMC 1997)
(a) Grew (b) Brown
(c) Robert Hooke (d) Darwin

707. In which of the following stages, the chromosome is thin and like a long thread?
(a) Leptotene (b) Zygotene
(c) Pachytene (d) Diakinesis

708. The amyloplasts look like: (AFMC 1997)
(a) Proplastids (b) Elaioplast
(c) Aleuroplast (d) Chloroplast

709. Which of the following has a single unit membrane organ? (BHU 1997)
(a) Mitochondria (b) Nucleolus
(c) Golgi body (d) Lysosome

710. Which is polymorphic organelle for suicidal bag? (CPMT 1997)
(a) Lysosome (b) Nucleus
(c) Ribosome (d) Mitochondria

711. Photorespiration takes place in: (BHU 1997)
(a) Peroxisomes (b) Mesosomes
(c) Lysosomes (d) Lomasomes

712. Enzymes for dark reaction are present in:
(a) Mitochondria (b) Cytoplasm
(c) Nucleus (d) Stroma of chloroplast

713. Endoplasmic reticulum is attached (continues) with: (BHU 1997)
(a) Ribosome (b) Golgi body
(c) Mitochondria (d) Nuclear membrane

714. Quinine is an alkaloid obtained from: (CPMT 1997)
(a) Bark of *Cinchona* tree (b) Leaves of *Cinchona* tree
(c) Root of *Cinchona* tree (d) Tuber of *Cinchona* tree

715. Main constituents of chlorophyll are: (CPMT 1997)
(a) Mg (b) Fe
(c) Both Fe, Mg (d) None of these

716. Core of chlorophyll is formed by:
(a) Fe (b) Mg
(c) CH_3 groups (d) Mn

717. What is absent in prokaryotic cell? (CPMT 1997)
(a) Nuclear membrane (b) Ribosomes
(c) Cytoplasm (d) None of these

718. Which is unsaturated fatty acid?
(a) Oleic acid (b) Palmitic acid
(c) Stearic acid (d) Arachidic acid

719. Centromere is a part of: (CBSE 1997)
(a) Endoplasmic reticulum (b) Mitochondria
(c) Chromosome (d) Ribosomes

720. "Cytoskeleton" consists of: (DPMT 1997)
(a) Cytoplasm
(b) ER
(c) Microtubules and microfilaments
(d) Cytoplasm with a network of microtubules and microfilaments

721. Glyoxysome was discovered by: (Raj. PMT 1997)
(a) Beevers (b) Tolbert
(c) Purkinje (d) Jansen and Jansen

722. The Singer and Nicolson model of plasma membrane differs from Robertson model in the: (BHU 1997)
(a) Number of lipid layers
(b) Arrangement of lipid layers
(c) Arrangement of proteins
(d) Absence of proteins in the Singer model

723. Electron transport system in mitochondria is situated on: (MPPMT 1997)
(a) Outer membrane (b) Inter-cristae space
(c) Internal membrane (d) None of these

724. Prokaryotes are characterised by: (CET Chandigarh 1997)
(a) Lack of nuclear membrane
(b) Lack of nucleolus
(c) Having dispersed DNA, lack of membrane bound organelles-like plastids and mitochondria
(d) All of the above

725. A nucleus is enclosed by: (MPPMT 1997)
(a) A non-porous double membrane
(b) A non-porous single membrane
(c) A porous double membrane
(d) A porous single membrane

726. Centrioles and centrosomes are present in the cell of: (CET Chandigarh 1997)
(a) A non-porous double membrane
(b) A non-porous single membrane
(c) A porous double membrane
(d) A porous single membrane

727. Cofactor of a conjugated enzyme is:
(a) Always organic
(b) Organic or inorganic
(c) Always inorganic
(d) Neither organic nor inorganic

728. In which of the following cells the number of mitochondria increases? (MPPMT 1997)
(a) Dormant seed (b) Germinated seed
(c) Dry seed (d) Dead seed

729. Plasma membrane is made up of: (CPMT 1997)
(a) Lipid and protein (b) Cellulose
(c) Pectin and cellulose (d) Chitin

730. Interphase nucleus is enclosed in: (BHU 1992)
(a) Non-porous nuclear membrane
(b) Porous double membrane
(c) Non-porous double nuclear membrane
(d) Two single unit membrane

731. Intercellular vacuole is not found in cell of: (MPPMT 1997)
(a) Lower plants (b) Higher plants
(c) Prokaryotes (d) Eukaryotes

732. Lomasomes were discovered by:
(a) Tolbert (b) Beevers
(c) Hanstein (d) Moore and McAllister

733. Which of the following structures is not found in higher plant cell? (CBSE 1997)
(a) Centromere (b) Spindle fibre
(c) Centriole (d) Cell wall

734. Sphaerosomes were discovered by:
(a) Hanstein (b) Dangeard
(c) Tolbert (d) Beevers

735. The function of nucleus is to synthesise: (MPPMT 1997)
(a) DNA (b) m-RNA
(c) r-RNA (d) t-RNA

736. The diameter of centriole measures:
(a) 100–150 mμ (b) 200–265 mμ
(c) 300–350 mμ (d) 400–450 mμ

737. Nucleus-less cell in mature stage is: (CBSE 1994)
(a) Companion cell (b) Cambium
(c) Sieve cell (d) Palisade tissue

738. The breadth of periplastidial space ranges between:
(a) 25–75 Å (b) 100–300 Å
(c) 300–400 Å (d) 400–500 Å

739. The living RNA, which is shortest is:
(a) t-RNA (b) m-RNA
(c) r-RNA (d) None of these

740. The plant cell which is longest is:
(a) Fibre (b) Tracheid
(c) Vessel element (d) Companion cell

741. Non-membranous cell organelles are: (MPPMT 1997)
(a) Mitochondria (b) Endoplasmic reticulum
(c) Ribosomes (d) Ribosomes and centrioles

742. Mitochondrion generally found in animals is:
(a) Cristae type (b) Tubulate type
(c) Both (a) and (b) (d) Intermediate type

743. The term ergastoplasm was given by:
(a) Carnier (b) Claude
(c) Sojstrand (d) Porter

744. Intracellular compartments are not found in the cells of: (MPPMT 1997)
(a) Lower plants (b) Prokaryotes
(c) Higher plants (d) Eukaryotes

745. Secondary lysosomes are formed when the primary lysosomes combine with:
(a) Residual bodies (b) Phagosomes
(c) Autophagosomes (d) None of these

746. The term lipochondria is applied for:
(a) Mitochondria (b) Golgi complex
(c) ER (d) All of these

747. What would happen if lysosomes get ruptured inside the cells in which they are present? (MPPMT 1997)
(a) Cells will swell (b) Cells will shrink
(c) Cells will die (d) Nothing would happen

748. The length of lampbrush chromosomes usually measures:
(a) 100–400 microns (b) 400–800 microns
(c) 1000–6000 microns (d) 6000–8000 microns

749. Necrosis is because of:
(a) Chloroplast (b) Ribosome
(c) ER (d) Lysosome

750. A flattened disc-like sac in a chloroplast discovered by Menke (1962) is called as: (MPPMT 1997; Pb. PMT 1997)
(a) Loculus (b) Thylakoid
(c) Stroma (d) Margin

751. Out of the following giant chromosomes, the larger one is:
(a) Polytene chromosome (b) Diplotene chromosome
(c) Both (a) and (b) (d) B-chromosome

752. One can measure the length of chromosomes at:
(a) Mitotic prophase (b) Meiotic prophase
(c) Mitotic metaphase (d) Meiotic metaphase

753. Leucoplasts are: (CET Chandigarh 1997)
(a) Plastids of variable colours
(b) Colourless plastids
(c) Proplastids
(d) Antiseptic adhesives

754. Golgi complex is specialised for: (BHU 1990)
(a) Energy transduction (b) Glycosidation of lipids
(c) Digestion (d) Conversion of energy

755. Golgi complex is derived from: (CPMT 1993; 2002)
(a) Smooth endoplasmic reticulum (SER)
(b) Nuclear membrane
(c) Cytoplasm
(d) Cell membrane

756. Which of the following has the largest plant cell? (MPPMT 1995)
(a) *Spirogyra* (b) *Acetabularia*
(c) *Chara* (d) *Ectocarpus*

*757. Which histone is absent in nucleosome? (Rohtak PMT 1994)
(a) H_1 (b) H_2
(c) H_3 (d) H_4

758. Factory for synthesis of sugars in autotrophic eukaryotes is: (AIIMS 1992)
(a) Chloroplast (b) Mitochondrion
(c) Endoplasmic reticulum (d) Ribosome

759. The pigment found inside the vacuole is: (MPPMT 1997)
(a) Anthocyanin (b) Hydrolase
(c) Phycocyanin (d) Phycoerythrin

760. Centrosome is responsible for: (Pondicherry 1997; Manipal 1997)
(a) Cell wall formation
(b) Cell plate formation
(c) Inhibition of cell division
(d) Initiation of cell division

761. The internal membrane is the extension of the infolded plasma membrane in: (AIIMS 1997)
(a) Golgi bodies (b) Mitochondria
(c) Endoplasmic reticulum (d) Plastid

762. Export firm of the body is: (AMU 1997)
(a) Golgi body (b) ER
(c) Nucleus (d) Mitochondria

763. Silica is found in: (CPMT 1998)
(a) *Ficus* (b) Horsetail and diatoms
(c) Rose (d) *Cycas*

764. Membrane surrounding vacuole in cell is: (CPMT 1998; 2002)
(a) Tonoplast (b) Desmosome
(c) Plasma membrane (d) Plasmodesmata

765. Cell to cell recognition in cell membrane is by: (CPMT 1998)
(a) Carbohydrate part (b) Lipid part
(c) Protein part (d) Nucleotides

766. The naturally found amino acids are mostly: (CPMT 1998; CBSE 2002)
(a) Laevo (b) Dextro
(c) Mixture of both (d) None of these

767. Who discovered the cell (actually the cell wall) in section of cork? (AFMC 1998)
(a) Schwann (b) Schleiden
(c) Robert Hooke (d) Leeuwenhoek

768. Microtubule is involved in: (CBSE 1998)
(a) Muscle contraction (b) Cell division
(c) DNA recognition (d) Membrane architecture

769. Lactose is composed of: (CBSE 1998)
(a) Glucose + Galactose (b) Glucose + Glucose
(c) Glucose + Fructose (d) Fructose + Galactose

770. The enormous diversity of protein molecules is mainly due to the diversity of: (CBSE 1998)
(a) Peptide bonds
(b) Amino groups on the amino acids
(c) 'R' groups on the amino acids
(d) Amino acid sequences within the protein molecule

771. Cellulose, the most important constituent of plant cell wall is made of: (CBSE 1998, 2002)

(a) Branched chain of glucose molecules linked by α-1,6-glycosidic bond at the site of branching
(b) Unbranched chain of glucose molecules linked by α-1,4- glycosidic bond
(c) Branched chain of glucose molecules linked by β-1,4-glycosidic bond in straight chain and α-1,6-glycosidic bond at the site of branching
(d) Unbranched chain of glucose molecules linked by β-1,4-glycosidic bond

772. Which organelle is not bound by two membranes? (CBSE 1999)
(a) Plastid (b) ER
(c) Nucleus (d) Ribosome

773. Which protein does not contain any metal? (CBSE 1999)
(a) Glycoprotein (b) Ferritin
(c) Cytochrome (d) Phytochrome

774. The secondary structure of the integral protein buried in the lipid bilayer of a cell membrane is: (CBSE 1999)
(a) B-strand (b) B-bend
(c) Random coil (d) α-helix

775. The most abundant biomolecule in the world is: (CPMT 1999; CBSE 2001)
(a) Starch (b) Cellulose
(c) Glycogen (d) Maltose

*776. Which of the following is a storage protein?(CPMT 1999)
(a) Glutelin (b) Pepsin
(c) Tubulin (d) Elastin

777. Which sugar is the main component of honey? (CPMT 1999)
(a) Polysaccharides (b) Monosaccharides
(c) Disaccharides (d) Trisaccharides

778. Lampbrush chromosomes are found in: (CPMT 1999)
(a) Salivary gland of *Drosophila*
(b) Salivary gland of honey bee
(c) Spermatocyte nuclei of *Drosophila*
(d) All of the above

779. Starch is converted to maltose by the enzyme: (CPMT 1999)
(a) Invertase (b) Diastase
(c) Amylase (d) Maltase

780. When corn is boiled in water, it attains sweetness because: (CPMT 1999)
(a) Starch changes into sugar
(b) Sugar changes into starch
(c) Glucose is converted into cellulose
(d) None of the above

781. Honey mainly contains: (BHU 1999)
(a) Glucose and fructose (b) Glucose and sucrose
(c) Sucrose and fructose (d) None of these

782. The term protoplasm was given by: (BHU 1999; MPPMT 2000)
(a) Dujardin (b) Purkinje
(c) Von Mohl (d) Robert Hooke

783. Which of the following is true for chlorophyll? (AIIMS 1999)
(a) Most abundant pigment (b) Self-replicating organelle
(c) Used in CO_2 fixation (d) None of these

784. Main component of middle lamella is: (AIIMS 1999)
(a) Pectin (b) Suberin
(c) Cellulose (d) Hemicellulose

785. Which of the following components is abundantly present in cell membrane? (AIIMS 1999)
(a) Protein (b) Lipid
(c) Carbohydrate (d) None of these

*786. The organelle of glycosylation is: (CBSE 2000)
(a) Peroxisome (b) Mitochondria
(c) Ribosome (d) ER

787. Starch is converted into maltose by: (CBSE 2000)
(a) Maltase (b) Sucrase
(c) Amylase (d) Iso-maltase

788. Which is a nutritionally essential amino acid? (CBSE 2000)
(a) Glycine (b) Tryptophan
(c) Proline (d) Phenyl alanine

789. Lysosomes are the store house of: (CBSE 2000)
(a) Enzymes (b) Hydrolytic enzymes
(c) Proteins (d) Fats

790. Lysosomes are formed by: (CPMT 2000)
(a) ER (b) Mitochondria
(c) Golgi bodies (d) None of these

791. According to Singer and Nicolson, plasma membrane contains: (CPMT 2000)
(a) Cellulose and hemicellulose
(b) Carbohydrates and protein
(c) Phospholipids and chitin
(d) Phospholipids, intrinsic and extrinsic proteins

792. Choose the correct statement: (CPMT 2000)
(a) All enzymes are proteins
(b) Some enzymes are proteins
(c) All enzymes and hormones are proteins
(d) All of the above

793. The term used for cell drinking is:
(a) Pinocytosis (b) Phagocytosis
(c) Exocytosis (d) All of these

794. Lysosomes act in: (CPMT 2000)
(a) Acidic pH (b) Basic pH
(c) Neutral pH (d) All of these

795. Function of nucleolus is: (CPMT 2000)
(a) Replication of DNA (b) Formation of ribosome
(c) Replication of RNA (d) Nuclear division

796. Which is concerned with secretion? (CPMT 2000)
(a) ER (b) Golgi body
(c) Mitochondria (d) Ribosome

797. Thylakoids are associated with: (CPMT 2000)
(a) ER (b) Golgi complex
(c) Mitochondria (d) Chloroplast

798. Amyloplasts store: (CPMT 2000)
(a) Fat (b) Starch
(c) Protein (d) Lipid

799. Which of the following is a phosphorylating unit? (AFMC 2000)
(a) Peroxisome (b) Oxysome
(c) Mesosome (d) Mitochondria

800. The simplest amino acid is: **(AFMC 2000)**
(a) Glycine (b) Proline
(c) Tryptophan (d) Leucine

801. How many types of cells are known? **(MPPMT 2000)**
(a) One (b) Two
(c) Three (d) Four

802. A mature plant cell has: **(MPPMT 2000)**
(a) Cell wall (b) Vacuole
(c) Protoplasm (d) All of these

803. In which plastids are not found? **(MPPMT 2000)**
(a) Blue-green algae (b) Bacteria
(c) Fungi (d) All of these

804. Semi-autonomous organelle is: **(MPPMT 2000)**
(a) ER (b) Lysosome
(c) Chloroplast (d) Prokaryon

805. The subunits of 80S ribosome are:
(MPPMT 2000; PMT Uttaranchal 2001)
(a) 30S and 50S (b) 40S and 60S
(c) 30S and 40S (d) None of these

806. Who discovered endoplasmic reticulum? **(MPPMT 2000)**
(a) Krebs (b) Altmann
(c) Porter (d) Swaminathan

807. Cystolith is a deposition of: **(MPPMT 2000)**
(a) Silica (b) Calcium oxalate
(c) Calcium carbonate (d) Tannin

808. What is deposited on cork cells? **(MPPMT 2000)**
(a) Lignin (b) Suberin
(c) Cutin (d) Pectin

809. What is the function of microtubules? **(MPPMT 2000)**
(a) Movement of cilia and flagella
(b) Formation of spindle fibres
(c) Both (a) and (b)
(d) Functions not known

810. Rod-shaped chromosome is called: **(MPPMT 2000)**
(a) Metacentric (b) Telocentric
(c) Acrocentric (d) Bacillus

*811. The subunits of chromatids are: **(MPPMT 2000)**
(a) Chromonemata (b) Chromomeres
(c) Telomeres (d) Secondary constrictions

812. Chloroplasts fix: **(MPPMT 2000)**
(a) O_2 (b) CO_2
(c) H_2 (d) N_2

813. Which are related with photorespiration? **(MPPMT 2000)**
(a) Sphaerosome (b) Lysosome
(c) Glyoxysome (d) Peroxisome

814. Cell eating is called: **(CET Karnataka 2000)**
(a) Osmosis (b) Diffusion
(c) Pinocytosis (d) Phagocytosis

815. A molecule of sedoheptulose has carbon atoms numbering:
(CET Karnataka 2000)
(a) 3 (b) 4
(c) 6 (d) 7

816. The chemical formula of chlorophyll-b is:
(CET Karnataka 2000)
(a) $C_{55}H_{72}O_5N_5Mg$ (b) $C_{55}H_{72}O_5N_4Mg$
(c) $C_{55}H_{70}O_6N_4Mg$ (d) $C_{55}H_{70}O_5N_5Mg$

817. Iodine test is used to detect:
(CET Karnataka 2000; DPMT 2003)
(a) Malaria (b) Typhoid
(c) Carbohydrates (d) Fats

818. Lysosomes contain: **(CPMT 2001)**
(a) Transferase enzymes (b) Hydrolytic enzymes
(c) Oxido-reductases (d) All of these

819. Site of attachment of ribosomes is: **(CPMT 2001)**
(a) ER (b) Lysosome
(c) Nucleus (d) Chloroplast

820. Number of protoplasmic amino acids is: **(CPMT 2001)**
(a) 10 (b) 20
(c) 30 (d) 80

821. Cristae are found in: **(CPMT 2001)**
(a) Mitochondria (b) Chloroplast
(c) Both (a) and (b) (d) None of these

822. Flow of substances into and out of the cell is done by:
(CPMT 2001)
(a) Plasma membrane (b) Cell wall
(c) Plasmodesmata (d) None of these

823. Cell theory was given by: **(CPMT 2001; Kerala PMT 2003)**
(a) Schleiden and Schwann (b) Knoll and Ruska
(c) Robinson and Brown (d) Robert Hooke

824. In plants inulin and pectin are: **(CBSE 2001)**
(a) Reserved materials (b) Wastes
(c) Excretory materials (d) Insect attracting materials

825. Element necessary for middle lamella is: **(CBSE 2001)**
(a) Ca (b) Zn
(c) K (d) Cu

*826. Microtubules are absent in: **(CBSE 2001)**
(a) Mitochondria (b) Flagella
(c) Spindle fibres (d) Centriole

827. An example of enucleated living plant cell is:
(PMT Uttaranchal 2001; CET Karnataka 2001)
(a) RBCs
(b) Xylem parenchyma
(c) Companion cells of phloem
(d) Sieve tubes of phloem

828. The plant cell differs from animal cell in:
(CET Karnataka 2001)
(a) Presence of large vacuole
(b) Presence of lysosomes
(c) Absence of chloroplast
(d) Absence of cellulosic cell wall

829. Extra-chromosomal DNA is found in: **(PMT Uttaranchal 2001)**
(a) Nucleus (b) Mitochondria
(c) Ribosomes (d) Chromosomes

830. Chitin is chemically: **(PMT Uttaranchal 2001)**
(a) N-acetyl muramic acid (b) N-acetyl glucosamine
(c) N-acetyl gluconic acid (d) None of these

831. Plants store food in the form of: **(PMT Uttaranchal 2001)**
(a) Glucose (b) Glycogen
(c) Sucrose (d) Starch

832. Prokaryotes differ from eukaryotes in lacking:
(PMT Uttaranchal 2001)
(a) Histones (b) DNA
(c) Both (a) and (b) (d) None of these

*833. Which of the following pairs is correctly matched as a unit and the structure which they collectively form? (Manipal 2001)
(a) Chlorophyll-a and -b — Chloroplast
(b) Thylakoids — Grana
(c) Cristae — Mitochondria
(d) Ribosomes — ER

834. The storage product in sugar cane and sugar beet is: (Manipal 2001)
(a) Glucose (b) Fructose
(c) Sucrose (d) Lactose

835. Pectin is a: (Manipal 2001)
(a) Monosaccharide found in cell wall
(b) Polysaccharide found in middle lamella
(c) Chemical found in blood
(d) Polymer of cellulose

836. Fluid mosaic model is: (Manipal 2001)
(a) A proposed structure for cell membrane
(b) A hypothetical model for cell wall
(c) A model of centriole structure
(d) None of the above

*837. Part of cell which contains various cell organelles but does not include them is: (Manipal 2001)
(a) Cytoplasm (b) Cytosol
(c) Protoplasm (d) Cell wall

838. Nucleolus helps in the formation of: (Manipal 2001)
(a) r-RNA (b) m-RNA
(c) t-RNA (d) Golgi body

839. Competitive inhibitors: (Manipal 2001)
(a) Inhibit the process by feedback inhibition
(b) Structurally resemble substrate and occupy active site
(c) Change the active site
(d) Form allosteric site

840. Maltose on hydrolysis yields: (Manipal 2001)
(a) Glucose + fructose (b) Glucose + galactose
(c) Glucose + glucose (d) Glucose + sucrose

841. The synthesis of lipids and lipoproteins is associated with: (MPPMT 2001)
(a) Endoplasmic reticulum (b) Mitochondria
(c) Chloroplast (d) Lysosomes

842. Unit membrane consists of: (MPPMT 2001)
(a) Lipid + Sugar + Lipid (b) Protein + Lipid + Protein
(c) Lipid + Protein + Lipid (d) Protein

843. Principal constituents of chromosomes are:(MPPMT 2001)
(a) DNA + Protein (b) DNA
(c) RNA (d) t-RNA

844. Which one of the following is not found in animal cell? (MPPMT 2001)
(a) Nucleus (b) Golgi bodies
(c) Chloroplast (d) Mitochondria

845. In eukaryotic cell the type of ribosome is: (MPPMT 2001)
(a) Only 70S (b) Only 80S
(c) 70S and 80S both (d) Only 50S

846. Eukaryotic cell has: (MPPMT 2001)
(a) Chromatin fibre (b) Definite nucleus
(c) Incipient nucleus (d) None of these

847. Shape of chromosome is determined by: (MPPMT 2001)
(a) Telomere (b) Centromere
(c) Chromomere (d) Centrosome

848. Which organelle of plant cells secretes polysaccharide and protein to make cell walls? (MPPMT 2001)
(a) Golgi bodies (b) Lysosome
(c) Mitochondria (d) Chloroplast

849. The genetic material of prokaryotic cells is called: (BHU 2001)
(a) Nucleus (b) Nucleolus
(c) Nucleoid (d) Chromosome

850. Nucleoli are rich in: (MPPMT 2001)
(a) RNA (b) DNA
(c) Protein and RNA (d) Carbohydrates

851. Dictyosomes are also known as: (BHU 2001)
(a) Golgi bodies (b) A class of ribosomes
(c) Respiratory particles (d) Place of flagellar origin

852. Which one is hexose sugar? [BCECE (P.T. Exam.) 2001]
(a) Mannose (b) Galactose
(c) Both (a) and (b) (d) Cellulose

853. Which organelle is not found in an animal cell? [BCECE (P.T. Exam.) 2001]
(a) Peroxisome (b) Ribosome
(c) Lysosome (d) None of these

854. Kinetochore is: [BCECE (P.T. Exam.) 2001]
(a) A type of chromophore
(b) Part of chromosome at centromere
(c) Part of centromere
(d) Constituent of chromomere

855. Golgi body is associated with: (CPMT 2002)
(a) Nucleus (b) Mitochondria
(c) Cytoplasm (d) Endoplasmic reticulum

856. Which of the following plastids are commonly found in cells not exposed to light? (CPMT 2002)
(a) Leucoplast (b) Chloroplast
(c) Chromoplast (d) Plastoquinone

857. Cutin is secreted by: (CPMT 2002)
(a) Periderm (b) Hypodermis
(c) Epidermis (d) Peridermis & hypodermis

858. Quantasomes occur on the surface of: (CPMT 2002)
(a) Plasmalemma (b) Thylakoids
(c) Nuclear envelops (d) Cristae of mitochondria

859. The main carbohydrate component as stored food in plant cell is: (CPMT 2002)
(a) Sugar (b) Starch
(c) Protein (d) Cellulose

860. Cellulose is: (CET J & K 2002)
(a) Hexose polysaccharide (b) Heptose polysaccharide
(c) Heteropolysaccharide (d) Pentosan polysaccharide

861. Prokaryotic cells occur in: (CET J & K 2002)
(a) PPLO (b) Bacteria
(c) Cyanobacteria (d) All of these

862. Animal cell differs from the plant cells in not having the: (CET J&K 2002)
(a) Cell wall (b) Plastids
(c) Glyoxysomes (d) All of these

863. Which of the following statements is incorrect with reference to lysosomes? (JIPMER 2002)
(a) They are filled with acid hydrolase and other enzymes
(b) They are monomorphic and uniform in structure and function
(c) They may be autophagic
(d) They can digest proteins, nucleic acids, lipids and polysaccharides

864. One molecule of an enzyme is needed to convert 2 molecules of a substrate into products in 5 minutes. 10 molecules of the enzyme and 25 molecules of substrate are mixed in a test tube. After 10 minutes the test tube will be having: (CET Karnataka 2002)
(a) Products, enzymes and 5 molecules of unreacted substrate
(b) Products and enzyme
(c) Products
(d) Products and 5 molecules of unreacted substrate

865. A polysome is formed by: (CET Karnataka 2002)
(a) Many m-RNAs being attached to a ribosome
(b) A cluster of ribosomal sub-units
(c) Many ribosomes attached to a m-RNA
(d) A cluster of ribosomes

866. In Singer and Nicolson model of plasma membrane the extrinsic proteins are: [BCECE (P.T. Exam.) 2002]
(a) Tightly associated with intrinsic protein and can be easily separated
(b) Loosely associated with intrinsic protein and can be easily separated
(c) Loosely associated with intrinsic protein and can't be easily separated
(d) Tightly associated with intrinsic protein and can't be easily separated

867. Protein packaging is done in: (DPMT 2001)
(a) Golgi apparatus (b) Ribosomes
(c) Endoplasmic reticulum (d) Nucleolus

868. The function of glyoxysomes is: (DPMT 2001)
(a) Protein metabolism
(b) Carbohydrate metabolism
(c) Fat metabolism
(d) Protein synthesis

869. Cells having secretory functions have abundant: (DPMT 2001)
(a) Lysosomes (b) ER
(c) Dictyosomes (d) Osteosomes

870. The primary structure of protein is made by: (Pb. PMT 2001)
(a) Hydrogen bonds (b) Ionic bonds
(c) Peptide bonds (d) None of these

871. Which structure of enzyme helps in making of active site? (Raj. PMT 2001)
(a) Primary (b) Secondary
(c) Tertiary (d) Quarternary

872. The living beings are made up of cells. This was stated by: (BHU 2002)
(a) Lamarck (b) Von Helmont
(c) Hugo de vries (d) Schleiden and Schwann

873. Pentoses and hexoses are the most common: (BHU 2002)
(a) Disaccharides (b) Monosaccharides
(c) Oligosaccharides (d) Polysaccharides

874. Which of the following sets of cell organelles contains DNA? (BHU 2002)
(a) Nucleus, ribosomes and chloroplasts
(b) Nucleus, mitochondria and chloroplasts
(c) Nucleus, ribosomes and mitochondria
(d) Mitochondria, ribosomes and chloroplasts

875. Who coined the term 'Zymase' for enzymes in yeast? (BHU 2002)
(a) Kuhne (b) Sumner
(c) Pasteur (d) Buchner

876. The photorespiratory carbon-oxidation cycle involves the interaction of: (AIIMS 2002)
(a) Chloroplast (b) Peroxisome
(c) Mitochondria (d) All of these

877. Which of the following is related to glycosylation of protein? (AIIMS 2002)
(a) Lysosome (b) Peroxisome
(c) Mitochondria (d) Rough ER

878. Which is a reducing sugar? (CBSE 2002)
(a) Galactose (b) Gluconic acid
(c) β-methyl galactoside (d) Sucrose

879. Enzymes performing hydrolytic function at highly acidic pH fall under the category of: (CBSE 2002)
(a) Hydrolases (b) Proteases
(c) Peroxidases (d) Decarboxylases

880. Enzymes are: (CBSE 2002)
(a) Functional protein (b) Structural protein
(c) Specified protein (d) Fibrous protein

881. Lipids are insoluble in water because lipid molecules are: (CBSE 2002)
(a) Hydrophilic (b) Hydrophobic
(c) Neutral (d) Zwittor ions

882. In fluid mosaic model of plasma membrane structure: (CBSE 2002)
(a) Phospholipid bilayer is sandwitched between protein layers
(b) Protein layer is sandwitched between phospholipid bilayer
(c) Phospholipid and protein layers are arranged alternately
(d) None of the above

883. Which of the following is a tetrose sugar? (St. Jones 2002)
(a) Ribose (b) Talose
(c) Mannose (d) Erythrose

***884.** A cell lacking nucleus would also lack: (St. Jones 2002)
(a) Plasma membrane (b) Mitochondria
(c) Chromosomes (d) Vacuoles

885. Integral proteins of cell membrane occur on/in: (AFMC 2002)
(a) Inner surfaces (b) Outer surfaces
(c) Phospholipid matrix (d) Inner and outer surfaces

886. Which of the following occurs more than one and less than five in a chromosome? (CBSE 2002)
(a) Chromatid (b) Chromomere
(c) Centromere (d) Telomere

887. If all the peptide bonds of protein are broken, then the remaining part is: (Raj. PMT 2002)
(a) Amide (b) Oligosaccharide
(c) Polypeptide (d) Amino acid

888. In eukaryotes which of the following is not found? (Haryana PMT 2001)
(a) Mesosome (b) Nucleus
(c) Ribosomes (d) Plastid

889. In an experiment radioactive substances are incorporated with amino acid, then maximum amount of radioactive labelled protein will be found in:(VVMC-Safdarjung 2001)
(a) ER co-ordinated with polysomes
(b) Plasma membrane
(c) Nucleolus
(d) Golgi bodies

890. The cell wall of plants is made up of cellulose which is: (MPPMT 2002)
(a) A lipid (b) A protein
(c) A polysaccharide (d) An amino acid

891. Cell sap is found in which cell organelle? (MPPMT 2002)
(a) Nucleolus (b) Chloroplast
(c) Vacuole (d) Golgi apparatus

892. Where are centrioles found? (MPPMT 2002)
(a) In most of the flowers (b) In animal cells
(c) In angiospermic roots (d) DNA

893. Liposomes in plants are also called: (MGIMS Wardha 2003)
(a) Sphaerosomes (b) Glyoxysomes
(c) Lysosomes (d) Peroxisomes

894. The chromosomes apart from the sex chromosomes are called as: (CMC, Vellore 2003)
(a) Allosomes (b) Autosomes
(c) Heterosomes (d) Lampbrush chromosomes

895. The enzyme needed in biological systems for joining two molecules is called: (BHU 2003)
(a) Lyases (b) Diastases
(c) Polymerase (d) Hydrolase

896. Which of the following is not concerned with movement of materials in and out of cells? (BHU 2003)
(a) Osmosis (b) Diffusion
(c) Active transport (d) Surface tension

897. Ribosomes are involved in protein synthesis in: (Orissa JEE 2003)
(a) Prokaryotes (b) Eukaryotes
(c) Both (a) and (b) (d) Viruses

898. Ribosomes are classified according to their: (Orissa JEE 2003)
(a) Sedimentation rate (b) Size
(c) Weight (d) Volume

899. Most abundant water insoluble polysaccharide of plant cell wall is: (Orissa JEE 2003)
(a) Cellulose (b) Hemicellulose
(c) Pectin (d) Lignin

900. Starch and cellulose have the following: (Orissa JEE 2003)
(a) Both are branched polysaccharides
(b) Both are storage products in cytoplasm
(c) Both are components of plant cell wall
(d) Both are composed of glucose

901. The endoskeleton of cell is made up of: (DPMT 2003)
(a) Deutoplasm (b) Protoplasm
(c) ER (d) Cell wall

*902. The tertiary structure of proteins containing the amino acid cysteine is achieved through: (Kerala PMT 2003)
(a) Hydrogen bonds (b) Disulphide bonds
(c) van der Waals' force (d) Ionic bonds
(e) Covalent bonds

903. Aleurone grains are: (B.V. Pune 2003)
(a) Fat (b) Protein
(c) Carbohydrates (d) Enzymes

904. "Nu body" was shown by: (B.V. Pune 2003)
(a) Woodcock (b) Johanssen
(c) Temin and Baltimore (d) Darlington

905. The process by which large molecules move out of the cell is called: (B.V. Pune 2003)
(a) Reverse phagocytosis (b) Phagocytosis
(c) Deplasmolysis (d) Plasmolysis

906. The term nucleolus was coined by: (CBSE 2003)
(a) R. Brown (b) R. Hooke
(c) Bowman (d) Hanstein

*907. Chondriosome was discovered by: (CBSE 2003)
(a) Tatum (b) Palade
(c) Sutton (d) Altmann

*908. β-oxidation of fat takes place in: (Pb. PMT 2003)
(a) Microsomes (b) Glyoxysomes
(c) Mitochondria (d) Ribosomes

909. Sweetest sugar is: (AFMC 2003)
(a) Glucose (b) Lactose
(c) Sucrose (d) Fructose

910. Which of the following remain absent in prokaryotes? (AFMC 2003)
(a) Nuclear membrane (b) Ribosome
(c) Cell wall (d) Cell membrane

911. An example of competitive inhibition of an enzyme is the inhibition of: (AIIMS 2003)
(a) Succinic dehydrogenase by malonic acid
(b) Cytochrome oxidase by cyanide
(c) Hexokinase by glucose-6-phosphate
(d) Carbonic anhydrase by CO_2

912. The waxy substance associated with cell walls of cork cells is: (Manipal 2003)
(a) Lignin (b) Hemicellulose
(c) Suberin (d) Cutin

913. Which is not a connection between plasma membrane of adjacent cell? (Jharkhand CECE 2003)
(a) Desmosomes (b) Tight junction
(c) Gap junction (d) Transverse junction

914. Which of the following is not present in cell vacuoles? (CET J & K 2003)
(a) Hydrolytic enzymes (b) Latex of rubber plant
(c) DNA (d) Anthocyanins of flowers

915. Which of these is saturated fatty acid? (AMU 2003)
(a) Stearic acid (b) Oleic acid
(c) Linoleic acid (d) Arachidonic acid

ANSWERS

1—c	2—a	3—c	4—c	5—d	6—c	7—c	8—b	9—d	10—a	11—d	12—b
13—c	14—a	15—c	16—c	17—a	18—c	19—c	20—b	21—a	22—c	23—c	24—c
25—b	26—a	27—d	28—a	29—c	30—d	31—b	32—c	33—d	34—b	35—d	36—c
37—a	38—d	39—c	40—d	41—d	42—a	43—b	44—a	45—c	46—b	47—d	48—b
49—b	50—d	51—b	52—d	53—b	54—b	55—d	56—d	57—c	58—c	59—b	60—c
61—b	62—b	63—d	64—d	65—a	66—b	67—b	68—d	69—b	70—d	71—a	72—b
73—c	74—c	75—a	76—c	77—b	78—c	79—c	80—c	81—c	82—b	83—d	84—d
85—b	86—b	87—d	88—c	89—d	90—c	91—c	92—d	93—c	94—b	95—d	96—b
97—a	98—a	99—b	100—c	101—c	102—c	103—c	104—c	105—d	106—a	107—c	108—c
109—c	110—b	111—b	112—b	113—c	114—c	115—c	116—c	117—b	118—b	119—b	120—b
121—b	122—b	123—d	124—c	125—b	126—c	127—d	128—b	129—d	130—d	131—b	132—c
133—b	134—b	135—d	136—b	137—d	138—b	139—a	140—b	141—d	142—d	143—a	144—c
145—c	146—d	147—b	148—c	149—c	150—b	151—b	152—b	153—b	154—b	155—c	156—b
157—d	158—b	159—c	160—c	161—c	162—c	163—d	164—c	165—d	166—d	167—d	168—d
169—d	170—c	171—d	172—b	173—d	174—a	175—d	176—d	177—b	178—c	179—c	180—b
181—a	182—c	183—c	184—b	185—c	186—b	187—d	188—b	189—c	190—d	191—b	192—c
193—b	194—a	195—a	196—c	197—c	198—c	199—a	200—c	201—a	202—d	203—b	204—d
205—a	206—c	207—d	208—d	209—c	210—d	211—c	212—d	213—c	214—a	215—b	216—d
217—c	218—b	219—d	220—c	221—a	222—c	223—c	224—b	225—b	226—b	227—b	228—c
229—c	230—c	231—a	232—a	233—b	234—b	235—b	236—c	237—c	238—d	239—d	240—a
241—a	242—b	243—c	244—b	245—d	246—a	247—b	248—a	249—a	250—a	251—a	252—c
253—b	254—b	255—b	256—a	257—a	258—d	259—b	260—d	261—a	262—d	263—d	264—b
265—d	266—d	267—b	268—b	269—b	270—b	271—c	272—b	273—c	274—c	275—b	276—d
277—c	278—b	279—c	280—c	281—a	282—a	283—d	284—d	285—d	286—c	287—a	288—b
289—b	290—c	291—b	292—b	293—b	294—b	295—c	296—c	297—c	298—c	299—d	300—d
301—b	302—a	303—d	304—b	305—c	306—d	307—a	308—b	309—b	310—b	311—c	312—c
313—b	314—a	315—a	316—d	317—d	318—a	319—c	320—b	321—d	322—c	323—d	324—b
325—b	326—c	327—b	328—d	329—b	330—c	331—c	332—d	333—a	334—a	335—c	336—d
337—d	338—a	339—b	340—b	341—a	342—d	343—a	344—b	345—c	346—a	347—b	348—a
349—b	350—c	351—c	352—c	353—a	354—c	355—c	356—c	357—c	358—d	359—a	360—c
361—b	362—a	363—b	364—b	365—c	366—a	367—a	368—c	369—c	370—b	371—c	372—a
373—c	374—c	375—c	376—d	377—a	378—d	379—c	380—a	381—a	382—b	383—d	384—b
385—a	386—d	387—c	388—c	389—a	390—a	391—d	392—c	393—b	394—b	395—d	396—d
397—d	398—d	399—c	400—d	401—a	402—c	403—b	404—a	405—c	406—a	407—b	408—b
409—a	410—b	411—b	412—a	413—d	414—b	415—d	416—c	417—d	418—c	419—c	420—b
421—c	422—c	423—c	424—b	425—b	426—d	427—c	428—a	429—d	430—b	431—d	432—c
433—c	434—b	435—c	436—b	437—c	438—a	439—b	440—a	441—b	442—c	443—d	444—a

445—b	446—d	447—a	448—b	449—b	450—d	451—c	452—b	453—b	454—b	455—c	456—a
457—c	458—a	459—d	460—a	461—c	462—b	463—b	464—c	465—b	466—c	467—c	468—a
469—c	470—c	471—a	472—b	473—c	474—b	475—c	476—c	477—c	478—c	479—d	480—c
481—c	482—b	483—d	484—b	485—b	486—d	487—b	488—b	489—c	490—d	491—c	492—d
493—b	494—c	495—d	496—b	497—a	498—b	499—a	500—b	501—c	502—b	503—b	504—b
505—c	506—c	507—c	508—d	509—d	510—b	511—d	512—c	513—a	514—b	515—c	516—d
517—c	518—b	519—c	520—d	521—b	522—c	523—c	524—c	525—a	526—a	527—d	528—b
529—a	530—b	531—d	532—a	533—a	534—c	535—c	536—c	537—c	538—a	539—b	540—c
541—b	542—d	543—c	544—a	545—c	546—d	547—b	548—d	549—c	550—b	551—a	552—c
553—b	554—c	555—b	556—c	557—b	558—c	559—c	560—c	561—a	562—c	563—c	564—a
565—c	566—c	567—c	568—d	569—a	570—c	571—c	572—a	573—d	574—c	575—d	576—a
577—d	578—b	579—c	580—a	581—c	582—b	583—b	584—a	585—c	586—c	587—c	588—b
589—d	590—b	591—b	592—c	593—c	594—c	595—b	596—b	597—b	598—b	599—b	600—a
601—d	602—d	603—b	604—d	605—b	606—c	607—d	608—d	609—a	610—b	611—d	612—d
613—b	614—c	615—d	616—b	617—b	618—a	619—d	620—b	621—c	622—c	623—d	624—c
625—a	626—b	627—c	628—d	629—b	630—c	631—c	632—d	633—b	634—d	635—c	636—b
637—c	638—d	639—b	640—c	641—a	642—c	643—d	644—a	645—c	646—d	647—c	648—b
649—d	650—b	651—c	652—c	653—d	654—c	655—b	656—d	657—a	658—a	659—a	660—c
661—a	662—d	663—b	664—d	665—a	666—c	667—c	668—c	669—b	670—d	671—c	672—c
673—c	674—b	675—c	676—c	677—c	678—c	679—c	680—d	681—c	682—c	683—d	684—d.
685—a	686—c	687—a	688—b	689—b	690—d	691—d	692—a	693—d	694—b	695—a	696—a
697—d	698—a	699—d	700—a	701—a	702—b	703—a	704—b	705—c	706—c	707—a	708—a
709—d	710—a	711—a	712—d	713—d	714—a	715—a	716—c	717—a	718—a	719—c	720—d
721—a	722—c	723—c	724—d	725—c	726—c	727—b	728—b	729—a	730—b	731—c	732—d
733—c	734—a	735—b	736—b	737—c	738—b	739—b	740—a	741—d	742—a	743—a	744—b
745—b	746—b	747—c	748—b	749—d	750—b	751—b	752—c	753—b	754—b	755—a	756—b
757—a	758—a	759—a	760—d	761—a	762—a	763—b	764—a	765—a	766—a	767—c	768—b
769—a	770—d	771—d	772—d	773—a	774—d	775—b	776—a	777—b	778—c	779—b	780—a
781—a	782—b	783—c	784—a	785—a	786—d	787—c	788—b,d	789—b	790—c	791—d	792—a
793—a	794—a	795—b	796—b	797—d	798—b	799—b	800—a	801—b	802—d	803—d	804—c
805—b	806—c	807—c	808—b	809—c	810—b	811—a	812—b	813—d	814—d	815—d	816—c
817—c	818—b	819—a	820—b	821—a	822—a	823—a	824—a	825—a	826—a	827—d	828—a
829—b	830—b	831—d	832—a	833—b	834—c	835—b	836—a	837—b	838—a	839—b	840—c
841—a	842—b	843—a	844—c	845—c	846—b	847—b	848—a	849—c	850—c	851—a	852—c
853—d	854—b	855—d	856—a	857—c	858—b	859—b	860—a	861—d	862—a	863—b	864—b
865—c	866—b	867—a	868—c	869—c	870—c	871—c	872—d	873—b	874—b	875—d	876—d
877—d	878—a	879—a	880—a	881—b	882—a	883—d	884—c	885—c	886—d	887—d	888—a
889—a	890—c	891—c	892—b	893—b	894—b	895—c	896—d	897—c	898—a	899—a	900—d
901—c	902—b	903—b	904—a	905—a	906—c	907—d	908—b	909—d	910—a	911—a	912—c
913—d	914—c	915—a									

EXPLANATION OF SELECTED QUESTIONS (*)

11. Schleiden was a botanist and he advocated that cell is the basic unit of plants.

22. During protein synthesis, a group of ribosomes is held on m-RNA to form polyribosome or polysome.

44. Centrosome and hence centrioles are present only in animal (human) cells and not in plant cells.

63. Digestion of intracellular substances (inside cell) is the main function of lysosomes.

71. Brownian movements are characteristic of colloids and not of life.

79. Viruses are still smaller than PPLO or mycoplasma but these are subcellular (comparable to cell organelles).

89. Anthocyanins are the pigments present in cell sap (vacuole) and not in chloroplast.

101. Genome of prokaryotes is having DNA but histones (basic proteins) are altogether absent here.

109. In fluid mosaic model of plasma membrane, in between extrinsic proteins, there are present intrinsic proteins and lipids.

111. Glucose is the monomer of both starch and cellulose, but it is α-D-glucose in starch and β-D-glucose in cellulose.

117. There are two sets of centrioles in a centrosome and two centrioles of each set are called diplosomes.

120. Ribosomes are ribonucleoprotein particles (r-RNA + proteins).

143. Lysosomes pass through different stages in the same cell (hence polymorphic).

150. In prokaryotes (bacteria), histones are not united with DNA and hence definite chromosomes are absent. Sometimes it is called single, naked chromosome.

181. Bending (angular deviation) of chromosomes and attachment of spindle fibres occur at primary constriction (not at secondary constriction).

192. Organic cofactors are of two types—coenzymes and prosthetic groups.

200. Protoplasm consists of organelles (living) and deutoplasm (non-living).

213. Hyaloplasm or cytosol = cytoplasm – organelles.

222. Cell size $\propto \dfrac{1}{\text{metabolic activity}}$.

246. Ripened fruits become soft due to dissolution of middle lamella.

253. Ribosomes are sites of protein synthesis everywhere.

254. Overall shape of membranes can change due to presence of lipids.

265. Sialic acid (N-acetyl neuraminic acid) is terminal sugar of oligosaccharide chains present in glycoproteins of plasma membrane.

284. In chloroplast, DNA is present.

317. In mitochondrion, DNA is present.

323. Terminal oxidation occurs in ETS of mitochondria.

327. In prokaryotes, oxidative enzymes are present in plasma membrane.

346. Cytochromes (electron carriers) are components of electron transport chain in mitochondria.

351. Cytoplasmic DNA (plasma genes or cytogenes) is present in mitochondria and chloroplast.

392. Sex chromosomes (X and Y) have been reported in monoecious plants like *Coccinia*.

400. Gametes may be gymnogametes (without cell wall) or calyptogametes (with cell wall).

427. Microsome is not an organelle; it is a fraction formed during ultracentrifugation.

439. Protein grains are called aleurone grains.

470. Prokaryotic ribosomes (70S) are also present in mitochondria and chloroplast.

486. Synthesis of proteins is regulated by DNA (present in nucleus).

491. Sphaerosomes are associated with formation and storage of lipids or fats (cutin and wax are lipids).

495. Anthocyanins present in cell sap are responsible for the colour of rose petals.

510. Nucleolar organizing chromosome is having a secondary constriction (called NOR).

512. Centriole and basal body have 9 + 0 arrangement.

520. Cell to cell recognition is a function of oligosaccharides of plasma membrane.

562. Extranuclear DNA is present in mitochondria and chloroplast.

650. Ribosome is present in both prokaryotes (Monera) and eukaryotes (Protista).

656. All enzymes of Krebs' cycle are present in matrix of mitochondria except succinic dehydrogenase, which is found attached to inner mitochondrial membrane.

669. Tubulin is characteristic protein of microtubules, which constitute cilia, flagella, spindle fibres, basal bodies, etc.

680. Three types of plastids are interchangeable.

757. Core of nucleosome is made of octamer of histones (2 molecules each of H_2A, H_2B, H_3 and H_4).

776. Glutelin is the common storage protein of cereals.

786. Glycosylation of proteins is done in rough ER.

811. Chromosome and chromatid (half chromosome or future chromosome) are made of long, coiled, filamentous structures running throughout the length, called chromonemata.

826. Microtubules (made of tubulin protein) form cilia and flagella, centriole and spindle fibres (not present in mitochondria).

833. Stack of thylakoids constitutes granum.

837. Cytosol or hyaloplasm is cytoplasm – cell organelles.

884. Chromosomes are present in nucleus.

902. Cysteine is a sulphur containing amino acid.

907. Chondriosomes are also called mitochondria.

908. Enzymes of fatty acid metabolism are present in glyoxysomes.

5

Energy Flow in the Life of a Cell

- Energy
- Laws of thermodynamics
- Exergonic and endergonic reactions
- Energy carriers and electron carriers in the cell
- Controlling metabolic reactions.

ENERGY

Energy is the fundamental component of any system. All living and non-living matter possesses energy, which may be defined as **the capacity to do work**. There is no physical phenomenon or chemical reaction which occurs without use of energy.

Energy is basically of two types:

4 1. **Potential energy:** The energy possessed by a body by virtue of its position or configuration is called potential energy. It is also called **stored energy**. Further it is not capable of doing work instantly. Different organic substances have potential energy.

4 2. **Kinetic energy:** The energy possessed by a body by virtue of its motion is called kinetic energy. This type of energy is released by breaking down of chemical bonds of organic substances and it is capable of performing different works.

In different systems, there is conversion of potential energy into kinetic energy and *vice-versa*. There are different forms of kinetic energy—electrical, radiant, thermal, mechanical, chemical, sound, nuclear, etc. Further, different forms of kinetic energy are also **interconvertible**.

- There are two types of energy changes in nature—**energy transfer** and **energy transformation** and both of these occur in living matter or cell.
- ATP (Adenosine triphosphate) is known as **energy currency** of cell as it can hand-over its energy to any reaction. 4 ATP is RNA-nucleotide or **ribonucleotide**, made of ribose sugar, adenine (N-base) and three phosphate groups. ATP was discovered by **Karl Lohmann** (1929) and its functioning was discovered by **Fritz Lipmann** (1941). Lipmann is also known as **'Father of ATP-Cycle'**. All living organisms use ATP as energy carrier.

LAWS OF THERMODYNAMICS

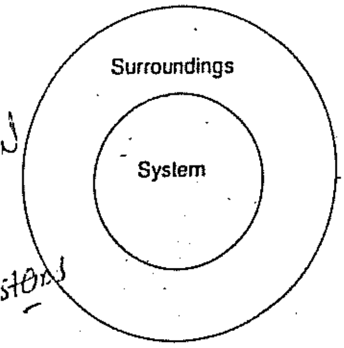
The branch dealing with energy changes or energy transformations is called thermodynamics. The branch of thermodynamics dealing with transformation and use of energy by living cells is called **biochemical thermodynamics** or **bioenergetics**.

Quantitative observations or interconversion of different forms of energy led to formulation of two **fundamental laws** of thermodynamics:

Thermodynamics

1. First law of thermodynamics (Law of conservation of energy): In thermodynamics, **system** (matter within a defined region) + **surroundings** (matter in rest of universe) constitute **universe**.

fundamental component of all system



'Universe' (System + Surroundings)

The first law of thermodynamics states that "The total amount of energy in the universe remains constant." or "Energy can neither be created nor destroyed but whenever it is used to do work or is converted from one form to another, the total amount of energy remains unchanged."

While doing work, energy is either transferred or transformed or both types of energy changes occur in a living cell. The first law of thermodynamics can be best understood in plants as follows:

Radiant energy or light energy from sun

↓ Photosynthesis in green cells

Chemical energy (food molecules) in form of potential energy*

↓ Respiration

Chemical energy is released and stored in the form of ATP molecules

↓

Utilized in different anabolic reactions like synthesis of macromolecules in cell and hence growth, development and repair.

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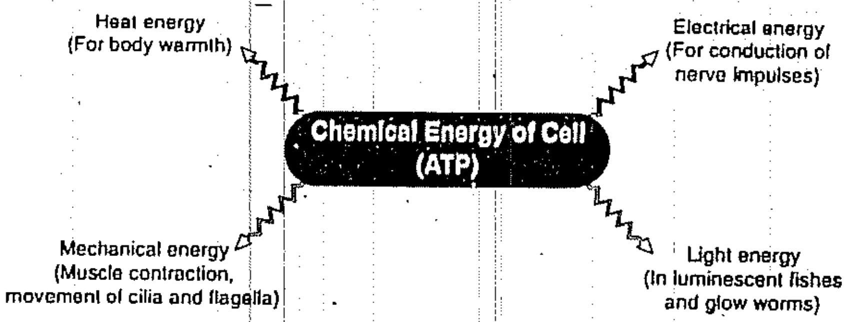
*Living world is dependent upon this transformation.

In a cell, chemical energy stored in the form of ATP is converted into different forms as shown below:


Heat energy
(For body warmth)
Electrical energy
(For conduction of nerve impulses)
Chemical Energy of Cell
(ATP)
Mechanical energy
(Muscle contraction, movement of cilia and flagella)
Light energy
(In luminescent fishes and glow worms)

Mathematically, first law of thermodynamics can be expressed as—

$$\Delta E = E_A - E_B = Q - W$$

where ΔE → Change in internal energy

E_A → Energy of a system in beginning of a process

E_B → Energy of a system at end of a process

Q → Heat absorbed by the system

W → Work done by the system.

- The change in energy of a system is dependent only on initial and final stages and not on the path of transformation.

2. **Second law of thermodynamics:** According to second law of thermodynamics, any system or universe has a tendency to increase 'Entropy' when left to itself because energy has a tendency of even distribution and it is transferred from high energy area to low energy area, (*i.e.*, in energetically downhill direction). Energy transfer through movement and collision of particles results in disorder of system or increase in entropy (denoted by the symbol 'S'), *i.e.*, entropy is a thermodynamic property which is used to measure the degree of randomness or disorder of a system. The term entropy was first used by **R. Clasius** (1851).

Further some energy is lost in the form of heat as a result of this disorder. This energy change and loss in the form of heat can be understood by the diagram given in Fig. 5.1 below.

Living system involves a huge number of chemical reactions and physical changes and all of these require energy changes (transfer or transformation of energy). As these energy changes are never cent per cent efficient so there is a continuous loss of energy from the living system, which leads to increase in entropy. The increase in entropy will lead to death of the living system unless the loss is made up through input of usable energy or free energy (*i.e.*, energy available to do work). This free energy decreases entropy. A living system or organism obtains free energy from environment either in the form of **sunlight** (*e.g.*, in autotrophs) or in the form of food. It is for this reason that a living system cannot be isolated from its environment. Such a system, which has a continuous influx of energy (directly or indirectly) is called **open system.** (On the other hand the system where there is no exchange with the surroundings is **called closed system.**)

- Further, open system is a system in a **steady-state** (homeostasis) as rate of input of matter and energy is equal to that of their output, *e.g.*, in a living organism (system), there should be continuous input of water, O_2, energy and variety of other materials and simultaneously, there should also be output of CO_2, nitrogenous waste materials, heat, etc.

Thus second law of thermodynamics expresses the concept that in occurrence of any event or process in the universe, there is decrease in availability of free energy and increase in entropy. Further, a process can occur spontaneously only if the sum of entropies of the system and its surroundings increases, *i.e.*,

$$\Delta S_{system} + \Delta S_{surroundings} > 0$$

First and second laws of thermodynamics together indicate that **energy of universe is constant but the entropy continues to increase to maximum.** The combined concept of two laws was put forward by the American chemist **J. William Gibbs** (1878) as follows:

$$\Delta H = \Delta G + T\,\Delta S$$

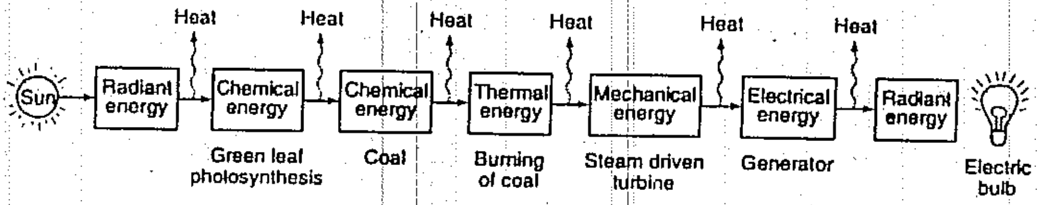

Heat
Heat
Heat
Heat
Heat
Heat
Sun
Radiant energy
Chemical energy
Chemical energy
Thermal energy
Mechanical energy
Electrical energy
Radiant energy
Green leaf photosynthesis
Coal
Burning of coal
Steam driven turbine
Generator
Electric bulb

Fig. 5.1. Energy transformation in a system (showing loss as heat in each change)

or

$$\boxed{\Delta G = \Delta H - T\Delta S}$$

where $\Delta G \longrightarrow$ Change in free energy of system (*i.e.*, change during a process in the energy available to do work).

$\Delta H \longrightarrow$ Change in enthalpy of system or change in heat content at constant pressure or total energy content of the system (equivalent to ΔE if change in volume is zero).

$T \longrightarrow$ Absolute temperature at which the process is taking place (K = °C + 273)

$\Delta S \longrightarrow$ Change in entropy of system

The above equation gives a measure of the spontaneity of a particular process. It also helps in predicting the direction in which a process will proceed and the extent to which the process will occur. All spontaneous energy transformations must have $-\Delta G$, *i.e.*, a process must proceed from a state of higher free energy to a state of lower free energy. In contrast if ΔG for a given process is +ve, then it cannot occur spontaneously. If ΔG is zero, then the system is present in equilibrium state.

EXERGONIC AND ENDERGONIC REACTIONS

Exergonic reactions

Processes or reactions that can occur spontaneously, *i.e.*, the reactions that are **thermodynamically favoured** are described as exergonic reactions. All such reactions have negative ΔG ($-\Delta G$). It means that the reaction or process must proceed from a state of higher free energy to a state of lower free energy. If ΔG is of great magnitude, the reaction goes virtually to completion and is essentially irreversible.

Or

In simple words, the reactions in which energy is released (*i.e.*, bond energy or stored energy is released) are called exergonic reactions. All catabolic or destructive processes (in which a complex substance breaks down to form simple substances) in living organisms are examples of exergonic reactions.

- The most common catabolic process or respiration is an example of exergonic reaction.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 686 \text{ kcal}$$

(In this reaction, ΔG (change in free energy of system) is −686 kcal/mol., *i.e.*, **free energy of reacting molecules has decreased.** This free energy released is stored in ATP bonds (38 ATP) which is used in performing different vital activities of the cell.

- Another most important chemical reaction in the cell is the hydrolysis of ATP (adenosine triphosphate), *i.e.*,

$$ATP + H_2O \longrightarrow ADP + iP$$

($\Delta G = -11.5$ kcal/mol)

$\Delta G°$ (standard free energy change) = −7.3 kcal/mol

or it is **exergonic reaction.**

Similarly,

$$\text{Palmitic acid} + 23O_2 \longrightarrow 16CO_2 + 16H_2O + \text{energy}$$

$$(\Delta G = -2338 \text{ kcal/mol})$$

$$\text{Maltose} + H_2O \longrightarrow 2\text{Glucose} + \text{Energy } (\Delta G = -3{\cdot}7\ )$$

$$\text{Dihydroxyacetone phosphate} \overset{\text{Isomerase}}{\rightleftharpoons} \text{3-phosphoglyceraldehyde}$$

$$(\Delta G = -0.7 \text{ kcal/ mol})$$

Endergonic reactions

If ΔG (free energy change) for a given process is positive ($+\Delta G$), then it cannot occur spontaneously or is thermodynamically unfavourable. All such **thermodynamically unfavourable** processes or reactions are called endergonic reactions. All such reactions have positive ΔG. Such reactions can proceed only if free energy can be gained. If ΔG is of high magnitude, the system is stable with little or no tendency for a reaction to occur.

Or

In simple words, the reactions in which energy is consumed are called endergonic reactions. All anabolic or synthetic or constructive processes in living organisms are examples of endergonic reactions, *e.g.*, synthesis of carbohydrates (photosynthesis), lipids, proteins, nucleic acids, etc., translocation of organic solutes, N_2-fixation, active absorption, growth and development, cyclosis, movements of protoplasm, etc.

- Photosynthesis in plants is one of the most important endergonic processes. Here light or radiant enegy is converted into chemical form of energy.

Here **assimilatory powers** (ATP and $NADPH_2$) produced in light reaction are utilized in assimilation or reduction of CO_2 in dark reaction of photosynthesis to carbohydrates, *i.e.*,

$$6CO_2 + 12H_2O + \underbrace{18ATP + 12NADPH_2}_{\text{Assimilatory powers or energy}} \longrightarrow$$

$$\underset{\text{Glucose}}{C_6H_{12}O_6} + 6O_2 + 6H_2O + 18ADP + 18iP + 12NADP$$

Both exergonic (destructive) and endergonic (synthetic) processes occur simultaneously in a cell. Generally, endergonic (synthetic) reactions exceed exergonic (destructive) reactions and growth is end product of this successful metabolism.

- ATP hydrolysis is used to drive most endergonic processes or reactions within the cell. Oxidation of carbohydrates, proteins and fats, etc., releases energy, which is used to bind ADP with iP (inorganic phosphate) to form ATP. This ATP (energy currency of cell) is used in different anabolic or endergonic processes of the cell or ATP acts as a **bridge** between exergonic and endergonic reactions or processes.
- Reactions that are normally endergonic can be made to occur by coupling them to exergonic reactions. An impor-

tant thermodynamic fact is that overall free energy change (ΔG) for a series of reactions is equal to the sum of the free energy changes of the individual step, *e.g.*,

First reaction: $A \rightarrow B$ $\quad \Delta G_1^\circ = -8$ kcal/mol

2nd reaction: $B \rightarrow C$ $\quad \Delta G_2^\circ = +5$ kcal/mol

Hence $A \rightarrow C$ $\quad \Delta G = \Delta G_1^\circ + \Delta G_2^\circ$

$$= -8 + 5 = -3 \text{ kcal/mol.}$$

Thus A can be spontaneously converted into C as ΔG is −3 kcal/mol ($-\Delta G$ means thermodynamically favourable reaction).

In other words, a thermodynamically unfavourable reaction (endergonic) can be driven by a thermodynamically favourable (exergonic) reaction.

ENERGY CARRIERS AND ELECTRON CARRIERS IN THE CELL

Energy carriers in the cell

There exists a mechanism within cells whereby the free energy available from oxidative reactions (exergonic reactions) may be utilized to drive endergonic reactions. This is accomplished by trapping this energy through the formation of a **special class of phosphatic compounds of high energy content, called Energy Carriers or Energy Acceptors.**

Some of the important Energy Carriers or Energy Acceptor compounds in a cell are as follows:

1. **Adenosine triphosphate (ATP):** Special carrier of free energy in a cell is adenosine triphosphate (ATP). ATP plays a central role in transfer of free energy from exergonic to the endergonic reactions in the cells.
    - ATP was discovered in extracts of skeletal muscles by **Karl Lohmann** (Germany) and by **Cyrus Fiske** and **Yellapragada Subbarow** (U.S.A.) simultaneously in 1929. Later on ATP was found to be present in cells of all animals, plants and microbes. **Fritz A. Lipmann** (1941) postulated that ATP is the primary and universal carrier of chemical energy in cells. Further, he also proposed ATP Cycle and hence he is called **'Father of ATP-Cycle'.**

ATP is **nucleotide** (structurally similar to nucleotide of RNA) in which **three phosphate groups** are attached to a nucleoside called **adenosine**. Adenosine (nucleoside) is made of ribose sugar (5C) to which an N-base adenine is attached at C-1. Three phosphate groups are attached at C-5 of ribose sugar of nucleoside. Attachment of one phosphate group forms adenosine monophosphate (AMP); two phosphate groups form adenosine diphosphate (ADP) and three phosphate groups form adenosine triphosphate (ATP). The second and third phosphates of ATP are attached by **high energy bonds** (pyrophosphate bonds) and these bonds have high transfer potential because these are held against great electrostatic repulsion. These are represented with the help of sigmoid curves (~). More energy is required for formation of high energy bonds. ATP makes up about 75% or more of the sum of all the three adenine ribonucleotides (AMP, ADP and ATP). Futher about 90% of ATP of a cell is stored in mitochondria. ATP $\rightleftharpoons$ ADP interconversion also occurs in mitochondria. The energy released in oxidation of organic substances (especially hexose sugar or glucose) is used in binding iP (inorganic phosphate) with ADP to form ATP. ATP is hydrolyzed as part of many biochemical processes. In most reactions, **ATP is hydrolyzed to ADP and inorganic phosphate (iP),** but in some cases it is hydrolyzed to AMP and inorganic pyrophosphate (iPP). Both of these reactions have essentially the same ΔG° (standard free energy change) of −7.3 kcal/mol. On the contrary, the ΔG° value of hydrolysis of AMP to yield adenosine and phosphate is much lower, *i.e.*, only −3.4 kcal/mol. Energy released in breaking of terminal high energy bond of ATP is used in different processes. Hence 'bond energy' of ATP is bio-energy.

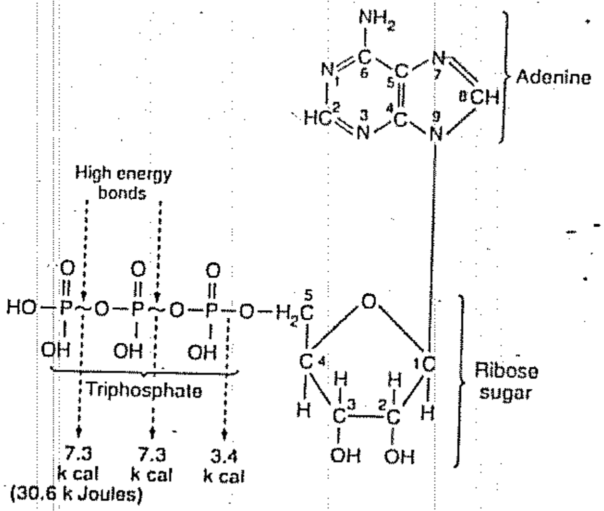


Fig. 5.2. Structure of ATP

- ATP serves as principal immediate donor of free energy in biological systems rather than as a storage form of energy. In a typical cell, an ATP molecule is consumed within a minute of its formation. ATP is also called 'Energy Currency' of cell. Synthesis and breakdown of ATP occur between exergonic and endergonic reactions of a cell, which constitute 'ATP-cycle or Energy Cycle'.

2. **Creatine phosphate and arginine phosphate:** These high energy phosphates (energy carriers) occur in muscles of vertebrates and invertebrates respectively.

During resting stage of muscles (under anaerobic condition), ATP combines with creatine to form creatine phosphate. During muscle contraction, breakdown of creatine phosphate occurs and free energy is stored in ATP again.

$$\text{ATP + Creatine} \rightleftharpoons \text{ADP + iP + Creatine}$$
$$\rightleftharpoons \text{Creatine phosphate + ADP}$$

3. Other energy carriers: Some biosynthetic reactions are driven by nucleotides that are analogous to ATP like guanosine triphosphate (GTP), cytidine triphosphate (CTP), uridine triphosphate (UTP). These are present in all cells but in lower concentration than ATP. Similarly, phosphoenol pyruvic acid (PEP), 1,3-diphosphoglyceric acid, acetyl phosphate and acetyl CoA are also high energy phosphates which act as energy carriers.

Electron carriers in cell

In some metabolic processes occurring in a living cell, hydrogen atoms (2H) are released which break down into protons ($2H^+$) and electrons ($2e^-$). These released electrons then pass through a series of some compounds or substances, called **electron carriers.** Each of these electron carriers is capable of existing in either an oxidized or reduced state. Each carrier is successively reduced by gain of electrons from the preceding carrier in chain and subsequently oxidized by loss of electrons to the next carrier. Thus electron acceptor and electron donor lie side by side, called **redox couple.** Further this passing of electrons over the carriers is called **electron transport system.**

- Electron carriers take part in different processes of cell, like cellular respiration, photosynthesis, biological N_2-fixation, etc.

Electron carriers in cellular respiration

Last step of aerobic respiration is oxidation of reduced coenzymes ($NADH_2$ and $FADH_2$) by molecular oxygen through a series of electron carriers—FAD, CoQ (coenzyme Q), Cyt. b, Cyt. c_1, Cyt. c, Cyt. a and Cyt. a_3. **The final acceptor of electrons is O_2,** which is reduced to water. Each electron carrier along the line has a **more positive redox potential than the previous one** and with each successive transfer, the electrons lose additional free energy. The free energy released by electron transfer is utilized to generate a **proton gradient,** which is utilized in endergonic formation of ATP. The $NADH_2$ formed in matrix of mitochondria (in TCA cycle) dissociates from its respective dehydrogenase and transfers its electrons to other carriers **associated with inner mitochondrial membrane.** There are approximately 20 electron carriers forming **electron transport chain** or respiratory chain. There are 4 types of membrane bound electron carriers:

(a) Flavoproteins
(b) Ubiquinone or CoQ
(c) Cytochromes
(d) Iron-sulphur proteins

- Except ubiquinone, all redox centres within electron transport chain are **prosthetic groups** (non-protein components) associated with proteins.

(a) **Flavoproteins:** These are made of a polypeptide which is bound tightly to either of two related prosthetic groups, *i.e.*, FAD (flavin adenine dinucleotide) or FMN (flavin mononucleotide). The prosthetic groups of flavoproteins are derived from vitamin B_2 or riboflavin and each of these is capable of accepting and donating two protons and two electrons. The major flavoproteins of the mitochondria are NADH dehydrogenase of electron transport chain and succinic dehydrogenase of Krebs' cycle.

(b) **Ubiquinone or Coenzyme Q (CoQ):** Next electron carrier of respiratory chain is ubiquinone (because of its ubiquitous nature, *i.e.*, occurring in all cells). Formerly, it was called coenzyme Q (Q for quinone). It is a **lipid soluble** molecule containing a long hydrophobic chain composed of 5-C isoprenoid units. Like the flavoproteins, each ubiquinone is able to accept and donate two electrons and protons.

- Ubiquinone is the only electron carrier in respiratory chain which is not tightly attached to a protein and it acts as a **highly mobile** carrier of electrons between flavoproteins and cytochromes.

(c) **Cytochromes:** These electron carriers are proteins that contain heme group as prosthetic group (oxygen molecule is bound to iron atom in the centre of heme group). Due to presence of heme group, cytochromes are **reddish** in colour.

- The cytochromes were discovered by a Scottish physician McMunn (1866), who named them as **histohematin** and **myohematin. David Keilin (1925)** renamed these pigments as cytochromes and recognized their role in biologic oxidation.

There are at least 5 types of cytochromes present in respiratory chain, *i.e.*, Cyt. b, Cyt. c_1, Cyt. c, Cyt. a and Cyt. a_3, which differ in substitutions within heme group. The iron atom in different cytochromes alternates between a reduced ferrous (Fe^{2+}) state and an oxidized ferric (Fe^{3+}) state during electron transport.

- Cytochrome c is the best known of the cytochromes. It is only electron transport protein which can be separated from the inner mitochondrial membrane by gentle treatment (soluble in H_2O). It is the smallest protein molecule (among cytochromes) having only 100 amino acids and mol.wt. 12500.
- Heme groups of cytochrome oxidase are also associated with Cu ions that play a key role in transferring electrons to O_2.
- Cytochromes act in sequence to carry electrons from ubiquinone to molecular O_2.

(d) **Iron-sulphur proteins:** This new group of electron-transport carriers in inner mitochondrial membrane was discovered in 1960. The iron atoms of iron-sulphur proteins are not located within a heme group but are closely linked to inorganic sulphur atoms as part of an iron-sulphur centre. The most common centres contain 2 or 4 atoms of iron and S. Even though a single centre may have several iron atoms, the entire complex is **capable of accepting and donating only a single electron.** More than a dozen iron-sulphur proteins have been identified within mitochondria and these are **closely associated with other electron carriers.**

- Various electron carriers form **four structural complexes** on inner mitochondrial membrane. Cyt. c and ubiquinone are not part of any of these complexes.

Complex I: NADH dehydrogenase (flavoprotein) + its 9 iron-sulphur centres. It catalyzes the transfer of pair of electrons from $NADH_2$ to UQ.

Complex II: Succinic dehydrogenase + its iron-sulphur centres. It provides a pathway for electrons from succinic acid to FAD to ubiquinone.

Complex III: Cyt. b + Cyt. c_1 + a specific iron-sulphur centre. It catalyzes the transfer of electrons from reduced ubiquinone to Cyt. c (not part of any complex).

Complex IV: Cyt. a + Cyt. a_3 (also called cytochrome oxidase). It catalyzes the final step in electron transport in mitochondria, *i.e.*, transfer of electrons to oxygen.

Electron carriers in photosynthesis

During cyclic and non-cyclic photophosphorylation, the released electrons from PS-I (P-700) or PS-II (H_2O) travel through electron transport chain consisting of A (FeS), Cyt. b_6, plastoquinone (PQ) cyt. f, plastocyanin (Pc) in cyclic photophosphorylation and Q (?), B (?), PQ, Cyt. f, PC, P-700, FeS, Fd, FAD and NADP in non-cyclic photophosphorylation. At certain points, enough energy is released, which is used to bind ADP with iP to form ATP.

(For details, see **photosynthesis** in plant physiology).

CONTROLLING METABOLIC REACTIONS

Metabolism is the collection of biochemical reactions that occur within a cell and it includes a tremendous diversity of molecular conversions. These reactions can be grouped into **metabolic pathways** containing a sequence of chemical reactions in which each reaction is catalyzed by a specific enzyme. The enzymes constituting a metabolic pathway are usually confined to a specific region of the cell, *i.e.*, mitochondria or the cytosol. Further, it is suggested that enzymes of a metabolic pathway are often physically linked to one another, a feature which allows the product of one enzyme to be used directly as a substrate to the active site of the next enzyme in the reaction sequence. The compounds formed in each step along the pathway are **metabolites or metabolic intermediates**, which lead to formation of **end product**. End products are molecules with a particular role in the cell. The metabolic pathways of a cell are interconnected at various points. Metabolic pathways are divided into two broad types.

(a) **Catabolic pathways** are those which lead to breakdown or disassembly of more complex molecules into simpler products. These pathways **firstly make the raw materials** available from which other molecules can be synthesized and **secondly,** they provide chemical energy required for many activities of a cell.

(b) **Anabolic pathways** are those which lead to synthesis of more complex compounds. These are energy requiring and utilize chemical energy released by exergonic (catabolic) processes.

Cells are highly efficient manufacturing plants that do not waste energy and materials in producing compounds that are not needed. The metabolic pathways are governed by a variety of **regulatory mechanisms** that are sensitive to the needs of the cell at the time:

1. **Enzymatic control:** Enzymes are the mediators of the metabolism, responsible for virtually every reaction that occurs in a cell. Without enzymes, metabolic reactions would proceed so slowly that life would not be possible.

Further enzymatic activity is affected by a number of factors as—

(i) Concentration of substrate Imp
(ii) Enzyme concentration
(iii) Temperature of medium
(iv) pH of medium
(v) Enzyme inhibitors including competitive and non-competitive inhibitors.
(vi) Feedback inhibition, etc.

Changing an enzyme's activity is usually accompanied by modifying the enzyme in a way that alters the shape of its active site. Two of the most common mechanisms for doing so are covalent modification and allosteric modulation.

- One of the primary mechanisms which the cells, use to shut down anabolic assembly lines is a type of allosteric modulation called **feedback inhibition,** in which the first enzyme in a metabolic pathway is temporarily inactivated when the concentration of end product of that pathway (*e.g.*, an amino acid, etc.) becomes more. Here the end product binds to the **allosteric site** (site spatially distinct from active site), causing a conformational change in the active site that decreases the enzyme's activity. Feedback inhibition provides a method for the cell to exert immediate and sensitive control over a cell's anabolic activity.

2. **Genic control:** Genes act by producing enzymes, *i.e.*, each gene in an organism produces a specific enzyme which controls a specific metabolic reaction. This 'one gene one enzyme' theory was given by **Beadle and Tatum,** for which they were given the Nobel Prize in 1958. If mutation occurs in a gene, synthesis of a specific enzyme will be stopped which will inhibit a particular metabolic process (controlled by that specific enzyme). Hence we can say that ultimately genes control metabolic reactions.

3. **Control by hormones:** Chemical substances secreted by ductless glands (endocrine glands) control the rate of metabolic reactions in animals. Similar is the case in plants, where phytohormones affect different metabolic processes which in turn control growth and development.

Besides these, metabolic processes are also controlled by environment, vitamins and nervous system.

MULTIPLE CHOICE QUESTIONS

1. Chief source of energy on earth is:
(a) Coal (b) Sun
(c) Moon (d) Natural gas

2. The type of energy released by breakdown of chemical bonds of organic substances and capable of performing different works is:
(a) Chemical energy (b) Kinetic energy
(c) Potential energy (d) Mechanical energy

3. Energy changes in nature are of type:
(a) Energy transfer (b) Energy transformation
(c) Both (a) and (b) (d) None of these

4. The stored energy which is not capable of doing work instantly is:
(a) Kinetic energy (b) Potential energy
(c) Mechanical energy (d) None of these

*5. A molecule of ATP is structurally similar to a molecule of: (Kerala PMT 2003)
(a) Deoxyribonucleotide (b) Ribonucleotide
(c) Protein (d) None of these

6. Functioning of ATP was first discovered by:
(a) Lohmann (b) Lipmann
(c) Clasius (d) Gibbs

7. The branch dealing with transformation and use of energy by living cells is called:
(a) Thermodynamics (b) Bioenergetics
(c) Energetics (d) Entropy

8. Who is called 'Father of ATP cycle'?
(a) Clasius (b) Lohmann
(c) Lipmann (d) Gibbs

9. Number of fundamental laws of thermodynamics are:
(a) 1 (b) 2
(c) 3 (d) 4

10. 'The total amount of energy in the universe remains constant', represents:
(a) First law of thermodynamics
(b) Second law of thermodynamics
(c) Both (a) and (b)
(d) None of the above

11. Energy transfer through movement and collision of particles results in:
(a) Decrease in entropy (b) Increase in entropy
(c) No change in entropy (d) None of these

12. A thermodynamic property which is used to measure the degree of randomness or disorder of a system is:
(a) Enthalpy (b) Entropy
(c) Free energy (d) Redox potential

13. The term entropy was first used by:
(a) J.W. Gibbs (b) R.Clasius
(c) Lipmann (d) McMunn

14. A system which has continuous influx of energy directly or indirectly is called:
(a) Closed system (b) Open system
(c) Both (a) and (b) (d) None of these

*15. Which system is in steady state or homeostasis?
(a) Open system (b) Closed system
(c) Both (a) and (b) (d) None of these

Genic control Genic
control

16. For occurrence of any process in the universe, there is:
(a) Decrease in free energy and increase in entropy
(b) Increase in free energy and decrease in entropy
(c) Decrease in both free energy and entropy
(d) Increase in both free energy and entropy

17. The combined concept of two laws of thermodynamics was given by:
(a) R. Clasius (b) J.W. Gibbs
(c) Lipmann (d) None of these

18. Which equation gives a measure of spontaneity of a particular process?
(a) $\Delta G = \Delta H + T\Delta S$ (b) $\Delta G = \Delta H - T\Delta S$
(c) $\Delta G = \Delta T - \Delta HS$ (d) None of these

19. A process can occur spontaneously, if ΔG for a given process is:
(a) Positive (b) Negative
(c) Zero (d) None of these

20. Thermodynamically favourable reactions are called:
(a) Exergonic reactions (b) Endergonic reactions
(c) Both (a) and (b) (d) None of these

21. Respiration is an example of:
(a) Exergonic reaction
(b) Endergonic reaction
(c) Thermodynamically unfavourable reaction
(d) None of the above

22. Which of the following acts as a bridge between exergonic and endergonic reactions of cell?
(a) ATP (b) $NADH_2$
(c) ADP (d) AMP

23. Which of the following is not energy carrier in a cell?
(a) ATP (b) Creatine phosphate
(c) GTP (d) Flavoproteins

*24. How many high energy bonds (pyrophosphate bonds) are present in a molecule of ADP? (CPMT 1995)
(a) 1 (b) 2
(c) 3 (d) 4

25. In hydrolysis of ATP to ADP, standard free energy change (ΔG°) is:
(a) –3.4 kcal/mol (b) –7.3 kcal/mol
(c) –11.5 kcal/mol (d) +7.3 kcal/mol

26. In ATP molecule, sugar present is:
(a) Ribose (b) Deoxyribose
(c) Glucose (d) Xylose

27. 'Energy currency' of cell is: (MPPMT 2002)
(a) AMP (b) ADP
(c) ATP (d) GTP

28. ATP of a cell is mainly stored in:
(a) Cytosol (b) Mitochondria
(c) Chloroplast (d) Nucleus

29. Final acceptor of electrons in electron transport chain in respiration is: (AFMC 1998)
(a) Cyt. c (b) Cyt. a_3
(c) O_2 (d) NAD

30. Which of the electron carriers in respiratory chain is not a prosthetic group associated with proteins?
(a) Cytochrome (b) Ubiquinone
(c) Flavoprotein (d) NAD

31. Highly mobile carrier of electrons between flavoproteins and cytochromes in respiratory chain is:
(a) CoQ (b) Cyt. c_1
(c) NADH dehydrogenase (d) Fe-S protein

32. Cytochromes were discovered by:
(a) D. Keilin (b) McMunn
(c) Lipmann (d) Lohmann

33. Which of the electron carriers are proteins containing heme group as prosthetic group?
(a) UQ (b) Cytochromes
(c) Flavoproteins (d) None of these

*34. Which of the electron carriers is ubiquitous in nature?
(a) CoQ (b) Cytochromes
(c) Flavoproteins (d) Fe-S proteins

35. Smallest protein molecule among cytochromes is:
(a) Cyt. b (b) Cyt. c
(c) Cyt. c_1 (d) Cyt. a

36. Which of the following electron carriers acts in sequence to carry electrons from ubiquinone to molecular O_2?
(a) NADH dehydrogenase (b) Iron-sulphur proteins
(c) Cytochromes (d) None of these

37. How many structural complexes of electron carriers occur on inner mitochondrial membrane?
(a) 1 (b) 2
(c) 3 (d) 4

38. Which of the following electron carriers are not part of any structural complex of electron carriers on inner mitochondrial membrane?
(a) Cyt. b and Cyt. a (b) Cyt. b and Cyt. c_1
(c) Cyt. c and ubiquinone (d) None of these

39. Electron carrier which can be separated from the inner mitochondrial membrane by gentle treatment is:
(a) Ubiquinone (b) NAD
(c) Cyt. c_1 (d) Cyt. c

40. Which of the electron carriers in respiratory chain is capable of accepting and donating only a single electron?
(a) Flavoproteins (b) Ubiquinone
(c) Cytochromes (d) Iron-sulphur proteins

41. Cytochrome oxidase (complex IV) of inner mitochondrial membrane is made of:
(a) Cyt. b + Cyt. c_1 (b) Cyt. a + Cyt. a_3
(c) Cyt. a + Cyt. b (d) None of these

42. Genes act by producing enzymes, was first advocated by:
(a) Beadle and Tatum (b) Hans Krebs
(c) J.W. Gibbs (d) H.G. Khorana

*43. Which of the following is not a high energy compound?
(a) ATP (b) GTP
(c) Creatine phosphate (d) AMP

*44. Ribozyme differs from enzyme in:
(a) Do not catalyze metabolic processes
(b) Do not occur inside cell
(c) Are not protein in nature
(d) All of these

45. Catabolic processes are:
(a) Exergonic (b) Endergonic
(c) Independent of energy (d) None of these

46. During formation of ATP from ADP, source of phosphate is:
(a) ATP (b) ADP
(c) Glucose-PO_4 (d) Inorganic phosphate (iP)

47. ATP is:
(a) Hormone
(b) Protein
(c) High energy phosphate compound
(d) Reducing enzyme

48. For cell movements, chemical energy is changed into:
(a) Mechanical energy (b) Electrical energy
(c) Thermal energy (d) Light energy

49. Cytochromes occur in:
(a) Mitochondria (b) Chloroplast
(c) Both (a) and (b) (d) None of these

50. Cytochromes in plant cells function mainly as: **[CPMT (R) 1992]**
(a) O_2 acceptor (b) CO_2 acceptor
(c) Electron acceptor (d) H_2O acceptor

*51. How many cytochromes are involved in the electron transport chain? **(AIIMS 1996)**
(a) Two (b) Four
(c) Five (d) Six

*52. Which of the following is related with vitamin B_2? **(AFMC 1997)**
(a) FMN/FAD (b) NAD
(c) NADH (d) None of these

53. Cytochrome has: **(AFMC 1999)**
(a) Magnesium (b) Manganese
(c) Copper (d) Iron

54. The high energy bonds of ATP are between: **(AIIMS 2001)**
(a) C—C (b) C—O
(c) C—N (d) O—P

55. The maintenance of internal favourable conditions by a self-regulated mechanism, inspite of the fact that there are changes in the environment, is known as: **(AIIMS 2001)**
(a) Entropy (b) Enthalpy
(c) Steady state (d) Homeostasis

56. The bond formed between the first phosphate group and adenosine in ATP is: **[CET (Karnataka) 2001]**
(a) Nitrophosphate bond (b) Adenophosphate bond
(c) Phosphoanhydride bond (d) Phosphoester bond

57. In the process of respiration, the potential energy stored in organic compounds is released in the form of: **(BHU 2001)**
(a) Physical energy (b) Radiant energy
(c) Kinetic energy (d) Chemical energy

58. ATP molecules combine with carrier molecules and flow: **(Pb. PMT 2000)**
(a) Along the concentration gradient
(b) Against the concentration gradient
(c) Both (a) and (b)
(d) None of the above

59. Which yields ATP during contraction of muscles? **(Pb. PMT 2001)**
(a) Myoglobin (b) Creatine phosphate
(c) Haemoglobin (d) Myosin

60. Energy is transformed by which cell organelles? (Raj. PMT 2001; Orissa JEE 2003)
   (a) Chloroplast and leucoplast
   (b) ER and mitochondria
   (c) Golgi body and mitochondria
   (d) Chloroplast and mitochondria

61. Which of the following is a component of electron transport chain in mitochondria? (DPMT 2001)
   (a) Phytochrome (b) Cytochrome oxidase
   (c) Plastocyanin (d) Carotenoids

62. In ATP, the high energy bond is the one which links: (CET Karnataka 2002)
   (a) Phosphate to phosphate (b) Ribose with phosphate
   (c) Adenine with ribose (d) Adenine with phosphate

63. Enzymes of electron transport system are present in : (CPMT 2003)
   (a) Inner mitochondrial membrane
   (b) Matrix
   (c) Intermembranous space
   (d) Endoplasmic reticulum

64. Which of the following accepts terminal electron? (CPMT 2003)
   (a) Molecular O_2 (b) Molecular H_2
   (c) Molecular CO_2 (d) $NADPH_2$

65. When spontaneous process occurs then free energy of the system: (DPMT 2003)
   (a) Decreases
   (b) Increases
   (c) Remains same
   (d) Either can increase or decrease

ANSWERS

1—b	2—b	3—c	4—b	5—b	6—b	7—b	8—c	9—b	10—a	11—b	12—b
13—b	14—b	15—a	16—a	17—b	18—b	19—b	20—a	21—a	22—a	23—d	24—a
25—b	26—a	27—c	28—b	29—c	30—b	31—a	32—b	33—b	34—a	35—b	36—c
37—d	38—c	39—d	40—d	41—b	42—a	43—d	44—c	45—a	46—d	47—c	48—a
49—c	50—c	51—c	52—a	53—d	54—d	55—d	56—d	57—d	58—b	59—b	60—d
61—b	62—a	63—a	64—a	65—a							

EXPLANATION OF SELECTED QUESTIONS (*)

5. Sugar present in ATP is ribose (5C), *i.e.*, the same as in ribonucleotides forming RNA.
15. As rate of input and output of energy and materials is same in open system.
24. In ADP, there is only one terminal pyrophosphate bond.
34. Due to its presence in all cells, ubiquinone or CoQ is ubiquitous (present everywhere).
43. As no pyrophosphate or high energy bond is present in adenosine monophosphate (AMP).
44. RNA molecules performing catalytic functions are called ribozymes.
51. In ETC or respiratory chain, there are 5 cytochromes as Cyt. b, Cyt. c_1, Cyt. c, Cyt. a and Cyt. a_3.
52. FMN and FAD are prosthetic groups of flavoproteins (electron carrier) and these prosthetic groups are derived from vitamin B_2 or riboflavin.

G1 S G2 M
30-40% 30-50% 10-20% 5-10%

6

Cell Division

- ☐ Meaning, why a cell divides?
- ☐ Different types of cell division—mitosis, meiosis, free cell formation, amitosis and budding
- ☐ Differences between mitosis and meiosis
- ☐ Karyotype analysis

All the cells arise from pre-existing cells by process of cell division. This phenomenon of production of daughter cells from parent cell is called **cell division**. The development of all multicellular organisms is by means of cell division.

Why a cell divides? There is a definite balance (ratio) between nucleus and cytoplasmic mass of cell called **Karyoplasmic ratio** or **Nucleo-cytoplasmic ratio** or **Kernplasma ratio**. Due to continuous cell growth, this balance or correlation (ratio) is disturbed, which leads to cell division. Further cell division is also necessary for continuity of organism or species.

TYPES OF CELL DIVISION

Different types of cell division are as follows:

(I) **Mitosis or mitotic cell division or equational cell division:** It leads to formation of daughter cells which are identical to parent cell in terms of number of chromosomes, *i.e.*, chromosome number remains the same.

(II) **Meiosis or meiotic division or reduction cell division:** It leads to formation of daughter cells, in which chromosome number is reduced to half as compared to parent cell.

- These above two are main types of cell division.

(III) **Free cell formation.**

(IV) **Amitosis.**

(V) **Budding.**

Cell cycle

Every dividing cell passes through four phases or stages, which collectively constitute the cell cycle (Mitotic cell cycle or Meiotic cell cycle).

Four phases of cell cycle are:

(i) **G_1-phase or post-mitotic phase or pre-DNA synthesis phase or first growth period or first gap period:** This phase is having high metabolic activities.

- Synthesis of proteins, RNA and ribosomes occurs during this phase.
- Time taken for completion of this phase is about 30–40% of the total cell cycle (mitotic cycle).
- Decision of cell division occurs during this phase.

(ii) **S-phase or DNA synthesis phase:** G_1-phase is followed by S-phase.

- This phase is characterized by synthesis of DNA (*i.e.*, DNA replication) as well as **histone proteins**.
- During this phase 'DNA polymerase' enzyme (responsible for DNA replication) is functionally active.
- Time taken for completion of this phase is 30–50% of total cell cycle.
- A cell would proceed to division (mitosis) without any interruption, when it has entered S-phase.

(iii) **G_2-phase or post DNA synthesis phase or second gap period or second growth period:** It follows S-phase.

- Time taken for completion of this phase is 10–20% of a total cell cycle.
- In this phase division of mitochondria and chloroplasts, division of centrioles and synthesis of proteins for spindle apparatus occur.
- Preparation of cell division occurs in this phase.
- All these 3 phases collectively constitute **interphase or resting phase, which is actually not resting phase but is most metabolically active phase.**

(iv) **M-phase or mitotic phase (or meiotic phase in meiosis) or actual cell division phase:**

- G_2-phase is followed by this actual dividing phase, *i.e.*, M-phase.
- Time taken for completion of this phase is **5–10%** of the total cell cycle and hence it is shortest of all the 4-phases.
- Thus,

$$\underbrace{G_1 + S + G_2}_{\substack{\text{Interphase or}\\ \text{resting phase}\\ \text{(long)}}} + \underbrace{\text{M–phase}}_{\substack{\text{Actual dividing}\\ \text{phase}\\ \text{(short)}}} \rightarrow \text{Cell cycle}$$

- Correct sequence of different phases of cell cycle is: G_1, S, G_2 and M.
- Time taken by these different phases varies in different organisms and also in different tissues of same organism, *e.g.*, in *Vicia faba* (Broad bean or Bakla), duration of different phases of cell cycle are:

Size of chromos. measu. Metaph. while shape be deter. at Anaph

Plant	Stage at which meiosis occurs
(i) *Chlamydomonas* (alga)	In zygote
(ii) *Ulothrix* (alga)	In zygospore
(iii) *Spirogyra* (alga)	In zygospore
(iv) *Rhizopus* or Bread mould (fungus)	In zygospore
(v) *Saccharomyces* or Yeast (fungus)	During formation of ascospores in ascus mother cell or ascus
(vi) *Riccia, Marchantia, Funaria,* etc. (Bryophytes)	In spore mother cell inside capsule of sporophyte
(vii) Ferns (Pteridophytes)	In spore mother cell inside sporangium
(viii) Gymnosperms (*e.g., Cycas, Pinus,* etc.) (ix) Angiosperms (Wheat, pea, etc.)	In microspore mother cells and megaspore mother cells inside microsporangia and megasporangia during formation of microspores (pollens) and megaspores.

- This reduction division may take place at any time in life cycle. Further the daughter cells resulting from meiosis are genetically distinct from parent cells.
- Meiosis always occurs in diploid cells called meiocytes.
- The anthers of onion or *Tradescantia* are considered to be the best material for study of meiosis.
- The stage of reduction division or meiosis varies from plant to plant. (See Table at the bottom of this page.)

With regard to time and place of occurrence of meiosis in life cycle of an organism, meiosis is of 3 types:

(a) **Gametic or Terminal meiosis:** In some lower plants, many protozoans and all animals, reduction division or meiosis occurs during formation of gametes before fertilization and this type of meiosis is called **gametic or terminal meiosis.** This type of life cycle having **diploid adult** and **gametic meiosis is called diplontic cycle.**

(b) **Zygotic or Initial meiosis:** In fungi, some algae and some protozoans, meiosis occurs immediately after fertilization in the zygote and thus the resulting adult organisms are haploid. This meiosis is called **zygotic or initial.** Such life cycle with **haploid adult** and **zygotic meiosis** is called **haplontic cycle.**

(c) **Intermediate or Sporogenic meiosis:** In all higher plants and some lower plants, **meiosis occurs at time of spore formation** (while gametes are formed by mitosis) and this is called **sporogenic or intermediate meiosis.**

Stages of meiosis

Meiosis consists of two successive divisions as:

(A) First meiotic division or meiosis I or actual reduction division or heterotypic division: It is accompanied with chromosome number reduction without any division of chromosome, *i.e.*, in this the chromosome number is reduced to half.

$$\text{Parent cell } (2n) \xrightarrow{\text{Meiosis I}} 2 \text{ cells } (n)$$

(B) Second meiotic division or meiosis II or homotypic division or equational division: It involves separation of chromatids of the chromosomes. Here 4 cells are produced from 2 cells and the chromosome number remains constant. So it is actually **mitotic or equational division** and hence sometimes called **meiotic mitosis.**

$$2 \text{ cells } (n) \xrightarrow{\text{Meiosis II}} 4 \text{ cells } (n)$$

- In meiotic cell cycle, there is interphase like mitosis (*i.e.*, $G_1 + S + G_2$), but here, G_2-phase is either very short or altogether absent, *i.e.*, meiotic division starts soon after S-phase (DNA synthesis phase).

(A) First meiotic division or Meiosis I

It is actual reduction division and is completed in 4 phases or stages.

(a) Prophase I
(b) Metaphase I
(c) Anaphase I
(d) Telophase I

(a) **Prophase I:** It is longest and most complex phase of meiosis I. It is further divided into 5 sub-stages as:

(i) Leptotene or leptonema
(ii) Zygotene or zygonema
(iii) Pachytene or pachynema
(iv) Diplotene or diplonema
(v) Diakinesis

(i) **Leptotene or leptonema:** Size of nucleus increases.

- In this sub-stage, the chromosomes appear as thin, uncoiled thread-like structures. One half of these chromosomes are of male parent and the other half of female parent. Chromosomes having similar characters or genes (which can pair) are known as homologous chromosomes.
- In some plants, *e.g., Lilium,* all the chromosomes are pointed at one end, which is called **synizesis** or **bouquet formation,** but its significance is not clearly known.

(ii) **Zygotene or zygonema:** Pairing or synapsis of homologous chromosomes takes place at this sub-stage, which is due to small amount of DNA replication at this stage (**Stern and Hotta,** 1969).

- Synapsis or pairing leads to formation of **bivalents.**
- Synapsis occurs in **zipper-like fashion** and may begin at centromere or at ends of chromosomes or at any point.
- Thickening and shortening of chromosomes occur.

(iii) **Pachytene or pachynema:** It is the longest sub-stage of prophase I. Chromosomes become further shorter and thicker.

- Each chromosome of homologous pair is having 2 chromatids at this stage and thus **bivalent** or homologous pair of chromosomes is now having **four chromatids** (four stranded) which is called **tetrad stage** or **tetravalent stage.**

- Crossing over (Exchange of chromosomal segments between non-sister chromatids of homologous chromosomes) occurs at this stage (at molecular level, however, expression at diplotene). Out of 4 chromatids of tetrad, only **two are cross-overs and two are non-cross overs.**
- Chromosomes at pachytene are more longer even than at mitotic metaphase, so morphological details of chromosomes can be best studied at this sub-stage.

(iv) **Diplotene or diplonema:** Chromosomes become still more shorter and thicker.

- As forces of attraction between homologous chromosomes or bivalents reduce, so they begin to separate from each other and this separation of homologous chromosomes is called **terminalization** (as separation starts from centromere towards ends).
- The separation is not complete, but the homologous chromosomes remain attached at one or more points and these points of contact are called **chiasmata.** Chiasmata are the points where crossing over takes place (but now it is considered that chiasmata are not causes but are consequence of crossing over).
- Number of chiasmata may be 1 or more depending upon the length of the chromosomes.
- Nuclear membrane and nucleolus begin to disappear at this sub-stage.

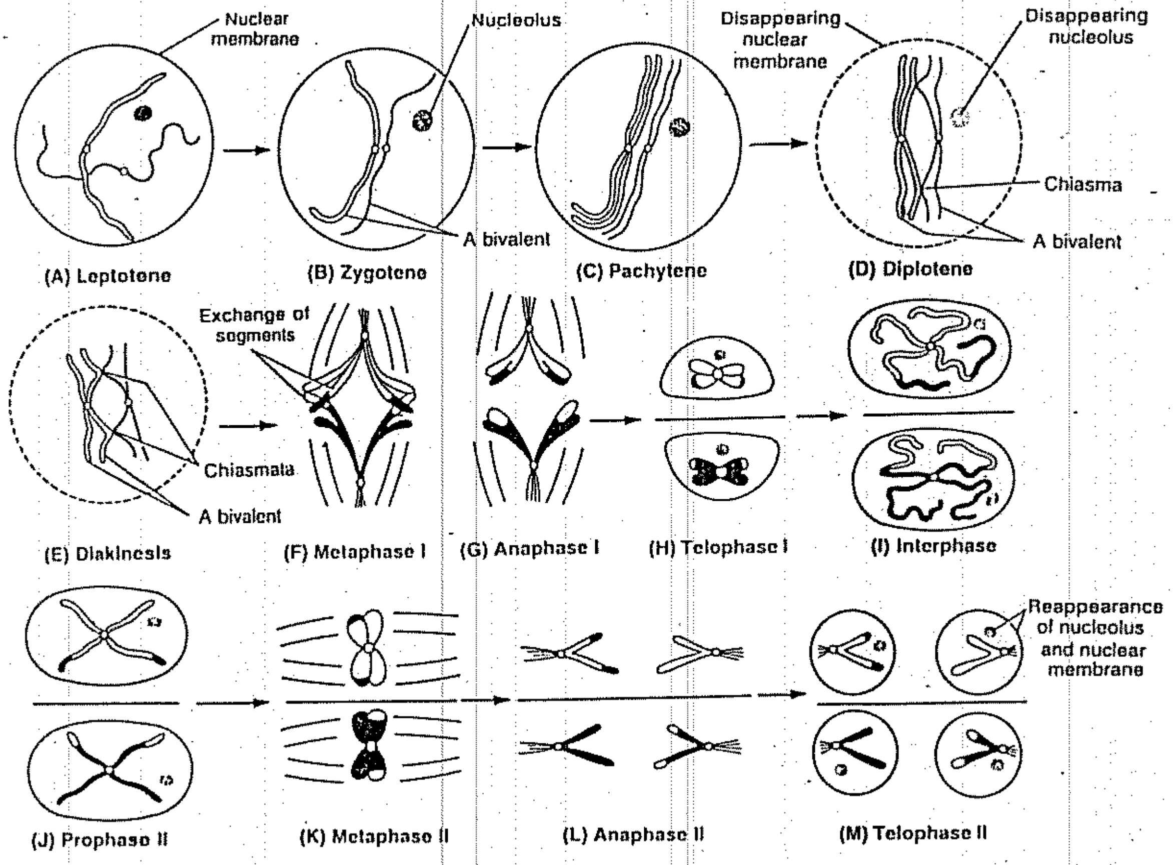
(v) **Diakinesis:** In this last sub-stage of prophase I, further contraction and shortening of chromosomes occur and chromosomes become minimum in size.

- **Terminalization** is almost complete.
- Both nucleolus and nuclear membrane completely disappear at this sub-stage (or in early metaphase).
- (Characteristic difference from **diplotene** is that chromosomes are shorter in **diakinesis**).

Synaptonemal Complex (SC): SC is a feature of meiotic prophase I, which was first observed by Moses (1956).

- SC is a **tripartite** (three-layered) protein framework (made of 2 lateral elements and one central element) found between two paired homologous chromosomes. **Ubiquitin** is the characteristic protein forming SC.
- Synaptonemal complex appears in **zygotene,** persists in **pachytene** (more conspicuous or clear) and disappears during **diplotene** sub-stage of prophase I.

Function of synaptonemal complex: It is believed that SC helps in **proper pairing of homologous chromosomes** and also **in producing recombinations.** This function is supported by period of appearance and disappearance of SC.



(A) Leptotene (B) Zygotene (C) Pachytene (D) Diplotene
(E) Diakinesis (F) Metaphase I (G) Anaphase I (H) Telophase I (I) Interphase
(J) Prophase II (K) Metaphase II (L) Anaphase II (M) Telophase II

Fig. 6.2. Different stages of meiotic cell division (meiosis)

G_1-phase	12 hrs
S-phase	6 hrs
G_2-phase	12 hrs
M-phase or mitotic phase	1 hr

- Therefore, cell cycle here is of 31 hrs (Interphase—30 hrs and mitotic phase—1 hr)
- Meiotic cell cycle has also interphase just like mitotic cycle consisting of G_1, S and G_2-phases; however here, G_2-phase is either **totally absent or very short**, *i.e.*, meiotic division (M-phase) occurs just after completion of DNA-synthesis (S-phase).

I. Mitosis or Mitotic cell division or Equational cell division

Mitosis or mitotic division is meant for **multiplication of cells.** Development of complete organism from zygote is by means of mitotic cell division. So mitosis is necessary for maintenance, growth, repair and continuity of life.

- Mitosis generally takes place in vegetative or somatic cells.
- In this process, one parent cell divides into two daughter cells, where chromosome number remains the same as in parent cell, *i.e.*, daughter cells exactly resemble with parent cell both **quantitatively as well as qualitatively.** So mitosis leads to increase in number of cells without any change in genetic make-up.
- Mitosis can be easily observed in meristematic cells of plant. **Root tips** (*e.g.*, onion root tips) are considered to be the best material for study of mitosis.
- **W. Flemming** (1882) gave the term mitosis (Gr.: *Mitos*-thread + *osis*-state). However, mitosis was first observed in plants by **E. Strasburger** (1875) and in animals by **W. Flemming** (1879).
- The actual **mitotic-phase** (M-phase) is completed in two steps:
  - (A) **Karyokinesis:** *i.e.*, division of nucleus into two.
  - (B) **Cytokinesis:** Karyokinesis is followed by **cytokinesis**, *i.e.*, division of cytoplasm into two cells or **wall formation.**

(A) Karyokinesis

Karyokinesis (division of nucleus) consists of the following four stages:

(i) Prophase
(ii) Metaphase
(iii) Anaphase
(iv) Telophase

* DNA is acidic. in nature.

(i) **Prophase:** After interphase, prophase comes, which is **first and longest stage of mitosis.**

- Prophase is most active of all the stages of M-phase.
- The chromosomes appear as thin, filamentous, uncoiled structures, which later on become coiled, shortened, thickened and more distinct by **spiralisation** (plectonemic coiling).
- **Longitudinal splitting or division** of each chromosome into two sister chromatids is another feature of prophase. These two sister chromatids are attached only at a point called **centromere** or **kinetochore** or **primary constriction.**
- **Nuclear membrane** breaks down to form membranous vesicles (In some primitive plants and animals like dinoflagellates, *Euglena, Microspora*, brown algae, etc., nuclear membrane does not dissolve).
- Nucleolus disappears or gets dispersed.
- Centrosome (particularly in animal cells) divides into two centrioles, which move to opposite poles.
- Spindle is also formed at late prophase (or early metaphase).
- Cell becomes viscous and refractive for the first time in prophase.

(ii) **Metaphase:** At this stage, the chromosomes become maximally distinct due to further contraction and thus size of the chromosomes is measured at mitotic metaphase.

- Due to attachment of spindle fibres at the centromeres of chromosomes, the chromosomes are arranged in the centre or at equator or equatorial plate or metaphase plate due to their active movements.
- In animal cells, spindle apparatus is formed due to division of centrosome or centriole, but in plants, spindle is still formed even in absence of centrosome in plant cells. Mechanism of the formation of spindle is, however, not clear in plant cells.
- In animal cells and lower plants, centrioles are present and asters (delicate fibres or microtubules), radiate from the centriole, which form spindle fibres. This type of mitosis is called **Astral or Amphiastral mitosis.** However, in higher plants, there are no centrioles and hence no asters are formed, so this type of mitosis is called **Anastral mitosis.** Spindle fibres are chemically made of 97% tubulin protein (protein of microtubules) and 3% RNA. Further spindle microtubules are polar with their polymerising '+' ends (fast growing) facing centre and non-polymerising '–' ends (slow growing) facing poles.

(iii) **Anaphase:**

- This is the **shortest stage** of mitosis.
- Chromosomes divide at the point of centromere or kinetochore and thus two sister chromatids are formed, which are now called chromosomes.
- Interzonal fibres appear between the daughter centromeres (*i.e.*, formed after division of centromere).
- **These sister chromatids or future chromosomes or daughter chromosomes now move towards the opposite poles** of spindle and this movement is due to **repulsion between centromeres, contraction of spindle fibres and relaxation of interzonal fibres.**
- Different shapes of chromosomes are observed at anaphase (V or J or L or I-shaped), depending upon position of kinetochore or centromere.
- * (Hence shape of chromosomes is determined at mitotic anaphase).

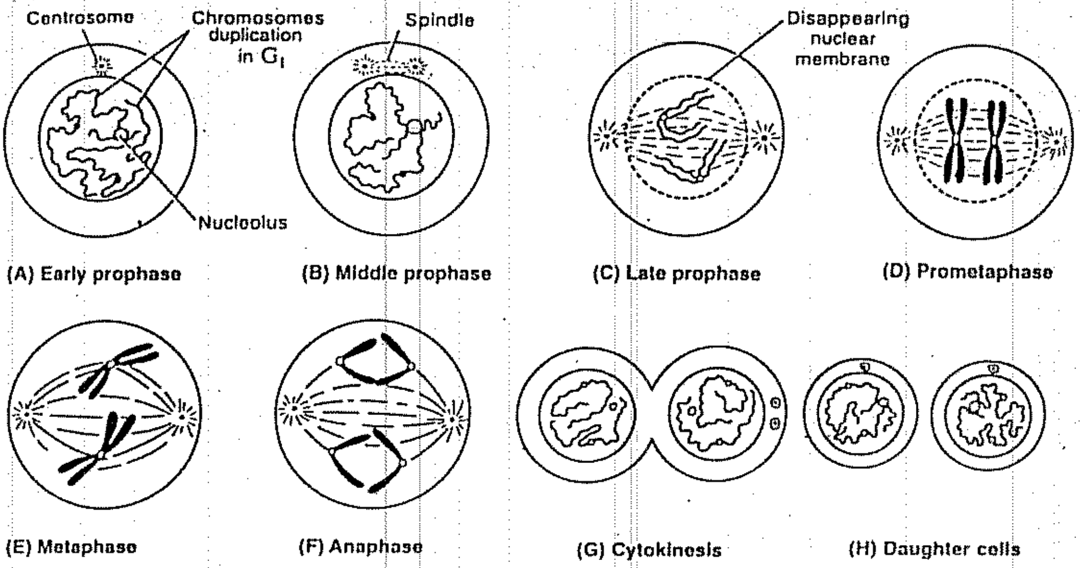


Fig. 6.1. Different stages of mitotic cell division (mitosis)

(iv) Telophase: Chromosomes reach opposite poles of the spindle.

- Chromosomes now become decondensed, uncoiled and not clear in outline (fuzzy).
- Disintegration of spindle fibres occurs at this stage and nuclear membrane reappears around each group of chromosomes. Nucleoli also make their appearance, thus forming **two daughter nuclei.**

(B) Cytokinesis

Karyokinesis results in formation of two nuclei inside a cell and now it is followed by division of cytoplasm (Cytokinesis), thus forming two cells (daughter cells).

- Cytokinesis is by 2 methods:
  (i) **Cell furrow method:** This is characteristic of animal cells. Due to absence of rigid cell wall here, the more flexible plasmamembrane forms the outer layer of cell. A **circular constriction** or invagination appears at centre or equator, which deepens gradually and finally two daughter cells are separated.
  (ii) **Cell plate method:** This is characteristic of plant cells. Here, vesicles provided by Golgi apparatus unite to form phragmoplasts, which join to form **cell plate.** Cell plate is **first laid down in centre** and then proceeds **towards periphery** (*i.e.*, centrifugal plate-formation). Cell wall materials are now laid down on both sides of cell plate and thus forming two daughter cells.
- Thus by **mitotic division or mitosis,** two daughter cells (exactly similar to parent cell) are formed from a single parent cell.
- Period of active mitosis or mitotic division ranges from **10 minutes to several hours.** Further higher the temperature, lesser will be the time taken.
- Colchicine is called **'Mitotic poison'** as it causes temporary cessation of mitotic division by inhibiting spindle formation.
- Uncontrolled cell division and increase in cell size leads to **tumour formation** or cancers. Main cancer causing agents (carcinogens) are radiations and chemicals like benzpyrene, aflatoxin, mustard gas vapours and vinyl chlorides.

Significance or role of mitosis

1. **Growth:** Mitotic divisions of vegetative or somatic cells are responsible for growth, maintenance and repair.

2. **Genetic stability:** Mitotic cell division results in daughter cells, which are both quantitatively and qualitatively similar to parent cell and thus responsible for genetic stability.

II. Meiosis or Meiotic cell division or Reduction cell division

- **Farmer and Moore** (1905) coined the term **meiosis** (*Meio*, to reduce) for the type of cell division in which a parent cell gives rise to four daughter cells, **which are having half the chromosome number** as compared to parent cell. Meiosis was first of all observed and studied by **Van Beneden (1887), Strasburger (1888), Sutton (1900) and Winiwarter (1900).**
- Meiosis is associated with reproductive or germinal cells.
- In organisms having sexual reproduction, a difficult situation may be created if the fusing sex cells in fertilization (*i.e.*, gametes) have same number of chromosomes as somatic cells, because zygote resulting from such fusion will be having double the chromosome number. This cycle will be repeated from generation to generation and there will be doubling of chromosomes again and again. In order to avoid this situation, nature has provided a type of cell division by which chromosome number is reduced to half in sex cells or gametes. This process by which reduction in chromosome number takes place is called **meiosis or reduction division.**

(b) **Metaphase I:** The chromosomes become more condensed and distinct. **Spindle apparatus** appears, the spindle fibres get attached to centromeres of bivalents and are arranged on equator due to **congression movements**. The arrangement of chromosomes on equatorial plate is such that **centromeres are towards poles** and chromosomal ends are towards equator.

(c) **Anaphase I:** In this stage, the movement of bivalents or chromosomes occurs towards the poles as a result of spindle fibres contraction and at the end of anaphase I, half chromosomes are at one pole and other half at other pole.

(d) **Telophase I:** This stage is similar to mitotic telophase. Nuclear membrane appears around the chromosomes at both ends or poles. Nucleoli also appear and thus **2 daughter nuclei** are produced from a single nucleus, having exactly half the number of chromosomes.

- Telophase I may or may not be followed by cytokinesis or wall formation.
- Resting period or interphase may or may not be present between meiosis I and meiosis II.

(B) Second meiotic division or Meiosis II

This meiotic division II is similar to **mitosis** or is equational division and hence it is sometimes called **meiotic mitosis.** This results in formation of 4 daughter nuclei from 2 daughter nuclei with exactly similar number of chromosomes.

Different stages are:

(a) Prophase II	(b) Metaphase II
(c) Anaphase II	(d) Telophase II

(Exactly similar to stages of mitosis).

Cytokinesis or wall formation: Karyokinesis (nuclear division) is followed by **division of cytoplasm**, *i.e.*, **cytokinesis,** which is of 2 types:

(i) **Successive type:** Here, both meiosis I and meiosis II are followed by wall formation and leads to formation of **isobilateral tetrads.**

(ii) **Simultaneous type:** Here, meiosis I is not followed by wall formation, but wall formation occurs simultaneously after meiosis II and thus leads to formation of **tetrahedral tetrads.**

Significance of meiosis

1. It maintains the **chromosome number constant from generation to generation.**
2. Meiosis leads to **recombinations** or new combinations of genes or characters as a result of crossing over. Due to these recombinations, variations are created, which have role in process of evolution.

III. Free cell formation

This type of cell division is characteristic of **endosperm tissue** or cells and is also found in development of gametophytes and embryos in gymnosperms.

- In this method, single nucleus undergoes free nuclear divisions (not accompanied by wall formation) forming a large number of free nuclei. After stoppage of nuclear division, wall formation occurs from periphery towards centre (*i.e.*, centripetal wall formation) and thus forming a cellular tissue.

IV. Amitosis

(*A* - not + *mitos* - thread), *i.e.*, division of nucleus without **recognizable or visible chromosomes is called amitosis.** It is also called **direct nuclear division.** Amitosis was first of all observed by **R. Remak** (1855) in RBC of chick embryo.

- In this type of cell division, usual features of mitosis like nuclear membrane disappearance and spindle formation, etc., do not occur but nucleus **divides by a constriction into two unequal nuclei.** Further this direct nuclear division may not be followed by wall formation.
- Amitosis is found in some lower algae, fungi (Thallophytes) and also in mature cells of higher plants, which are about to disintegrate.

V. Budding

This type of cell division is common in *Saccharomyces* (yeast). Here, small outgrowths or protuberances (buds) arise from cell and part of nucleus after dividing by mitosis or amitosis migrate into these outgrowths, which now develop into new cells. These buds or cells on separation lead independent life.

DIFFERENCES BETWEEN MITOSIS AND MEIOSIS

Mitosis	Meiosis
General:	
1. This division takes place in all kinds of cells and may continue throughout life.	1. It usually occurs in reproductive cells just before formation of gametes or spores in the life cycle of a plant.
2. Nucleus undergoes a single division at the completion of division cycle. Similar is the case with chromosomes.	2. Nucleus undergoes two divisions, first is reductional while second is equational, at the completion of division cycle, while the chromosomes divide only once, *i.e.*, in anaphase II.
3. Two daughter cells are formed at the end of mitosis.	3. Four daughter cells are formed at end.
4. The chromosome no. remains constant in daughter cells like parent cell, *i.e.*, daughter cells are genetically identical to parent cell.	4. The chromosome no. is reduced to half in daughter cells as compared to parent cells, *i.e.*, daughter cells are genetically different from parent cell.
5. Mitosis is much shorter.	5. Meiosis is much longer.
6. Mitosis may occur in diploid or haploid cells.	6. Meiosis always occurs in diploid cells (meiocytes).

Contd.

Mitosis	Meiosis
Prophase:	
7. Prophase is short and is without sub-stages.	7. Prophase I is prolonged with 5 different sub-stages as leptotene, zygotene, pachytene, diplotene and diakinesis.
8. There is no pairing of homologous chromosomes (synapsis) and hence no chance of crossing over and chiasmata formation.	8. Homologous chromosomes pair during zygotene sub-stage of prophase I and often undergo crossing over and hence forming chiasmata.
9. No synaptonemal complex (SC) is formed between chromosomes.	9. Synaptonemal complex (tripartite protein framework) is formed between pairing homologous chromosomes.
10. The chromosomes are longitudinally split into two sister chromatids during early prophase, *i.e.*, prophase chromosomes appear double from the very beginning.	10. The chromosomes are not longitudinally split but appear as single thread, *i.e.*, prophase I chromosomes do not appear double in the beginning.
11. Chromosomes do not unfold and there is no transcription and protein synthesis in prophase.	11. Chromosomes unfold and there may occur transcription and protein-synthesis during diplotene sub-stage of prophase I.
Metaphase:	
12. All chromosomes form a single plate in metaphase.	12. Chromosomes form 2 parallel plates in metaphase I and one plate in metaphase II.
13. On equatorial plate, chromosomes appear two threaded.	13. On equatorial plate, chromosomes appear four threaded in metaphase I, while metaphase II is similar to metaphase of mitosis.
Anaphase:	
14. Splitting of centromere of chromosomes and hence separation of 2 chromatids of each chromosome occurs at anaphase.	14. There is no splitting of centromeres in anaphase I and there is separation of homologous chromosomes in anaphase I. In anaphase II, splitting of centromeres and hence separation of chromatids occurs.
Telophase:	
15. Telophase occurs in all cases.	15. In some cases, telophase I is omitted.
16. Daughter cells have same number of chromosomes as parent cell.	16. At the end of telophase I, chromosome number is reduced to half.
Cytokinesis:	
17. Karyokinesis (division of nucleus) is usually followed by cytokinesis (wall formation).	17. Sometimes cytokinesis does not occur after telophase I or meiosis I, but it always occurs after meiosis II or telophase II, thus forming 4 cells simultaneously.
Significance:	
18. Mitosis is responsible for growth, repair and healing.	18. Meiosis is responsible for maintaining chromosome number constant from generation to generation, forms gametes or spores and also produces variations due to crossing over.

KARYOTYPE ANALYSIS

The term Karyotype is used for group of characteristics of chromosomes (*i.e.*, number, size, shape of individual chromosomes, position of centromere, secondary constriction and satellites, etc.) that identifies a particular chromosome set.

or

A **Karyotype** is a photographic inventory of an individual's chromosomes. In a karyotype, there is an orderly display of magnified images of the individual's chromosomes.

- A karyotype of a species is represented with the help of a diagram called **idiogram.** In idiogram, chromosomes of a haploid set of an organism are arranged in order of their decreasing size.

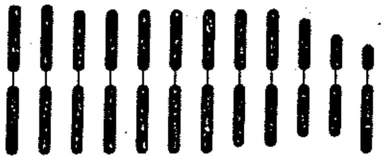
There are two basic types of karyotypes.

1. Symmetric Karyotype: A karyotype showing small differences between smallest and largest chromosome of haploid set and having comparatively more metacentric chromosomes is called **symmetric karyotype.** This type of karyotype is considered to be relatively **primitive** feature.

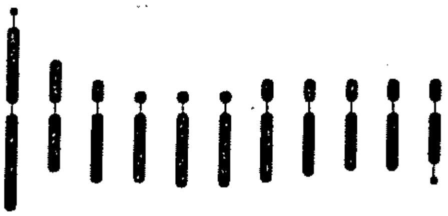
2. Asymmetric Karyotype: A karyotype showing large differences between smallest and largest chromosome of haploid set and having comparatively fewer metacentric chromosomes is called **asymmetric karyotype.** This type of karyotype is considered to be relatively **advanced** feature.

Following techniques are used for preparation of karyotype:

(i) Banding technique: This is very useful technique for



A. *Pinus*



B. *Ginkgo biloba*

Fig. 6.3. A. A symmetric karyotype B. An asymmetric karyotype

preparation of karyotypes. For the last 25 years, human chromosomes have been studied using **G-banding, C-banding** and **R-banding**. When subjected to certain treatments and then stained with chemical dye **Giemsa,** chromosomes generate series of bands, which help in identification of each chromosome along with any structural changes. C-bands and N-bands have been used in plant karyotyping.

(ii) **FISH (Fluorescence *in situ* hybridization and McFISH (Multicolour fluorescence *in situ* hybridization:** In this technique DNA probes (lebelled with radioactive or non-radioactive molecules) are used to find or locate the specific DNA sequences on chromosomes. In McFISH, fluorochromes are used to lebel DNA to allow use of one or more colours in order to locate the position of one or more DNA sequences simultaneously on the same chromosome.

(iii) **Flow cytometry:** This is recent technique in which chromosomes are first isolated from metaphase cells by hypotonic lysis and then suspended chromosomes are stained with a DNA binding fluorochrome. These chromosomes are passed through cytometer and fluorescence is measured in individual chromosomes. This is very accurate technique and can detect differences as small as 1.5–4.0 Mbp in chromosomes.

symmetric
Karyotype
Symmetric

Uses of Karyotyping or Karyotype Analysis

(i) After comparing the karyotypes of different groups of organisms, sometimes similarities are observed in karyotypes, which are presumed to represent evolutionary relationships.

(ii) Primitive or advanced features of an organism are also suggested by karyotype. Asymmetric karyotype is considered to be relatively advanced feature whereas symmetric karyotype is considered to be relatively primitive feature. A trend towards karyotype asymmetry is observed in flowering plants. Further increased karyotype asymmetry is found to be associated with specialized zygomorphic flowers.

(iii) Errors in meiosis may lead to gametes containing chromosomes in abnormal numbers or with major structural changes in chromosomes. Fertilization involving these types of abnormal gametes results in offsprings with chromosomal abnormalities. All such conditions can be easily detected by preparing a karyotype. Among the alterations in chromosomal number detected by karyotyping is **trisomy 21** (basis of Down syndrome). By flow cytometry technique of karyotype preparation, it is possible to detect difference as small as 1.5–4.0 Mbp (mega base pairs) and thus any structural change such as deletion, duplication, etc., in individual chromosomes, can be detected easily.

MULTIPLE CHOICE QUESTIONS

1. A cell divides in order to:
(a) Maintain size of nucleus
(b) Maintain bulk of cytoplasm
(c) Maintain balance between bulk of cytoplasm and nucleus
(d) Maintain size of chromosomes

2. Mitosis occurs in:
(a) Vegetative cells (b) Reproductive cells
(c) Mature cells (d) All of these

3. The cell structure which always disappears during mitosis is:
(a) Plastids (b) Plasmalemma
(c) Nuclear envelope (d) Ribosomes

4. Karyokinesis means the division of:
[✓ (a) Nucleus into two] (b) Cytoplasm into two
(c) Protoplasm into two (d) None of these

5. In which of the following stages of cell division is DNA content doubled? (MPPMT 2001, 2002)
(a) G-phase [✓ (b) S-phase]
(c) Metaphase (d) G_2-phase

6. Which is the longer phase during mitotic division?
[✓ (a) Prophase] (b) Metaphase
(c) Anaphase (d) Telophase

7. At anaphase stage of mitosis occurs:
(a) Nuclear division (b) Division of cytoplasm
(c) Replication of DNA [✓ (d) Division of chromosome]

*8. During cell division chromosomes move towards different poles due to:
(a) Centriole (b) Mitochondria
(c) Cytokinesis [✓ (d) Microtubules]

9. Amitosis is commonly found in certain:
[✓ (a) Angiosperms] (b) Bryophytes
[✓ (c) Thallophytes] (d) Pteridophytes

10. During cell division, nuclear envelope reappears in:
(a) Interphase (b) Prophase
[✓ (c) Telophase] (d) G_2-phase

11. Nuclear membrane disappears at:
(CPMT 1990, 96; CMC, Vellore 2003)
[✓ (a) Early prophase stage] [✓ (b) Late prophase]
(c) Metaphase (d) Anaphase

12. The cell becomes viscous and refractive for the first time in:
[✓ (a) Prophase] (b) Interphase
(c) Anaphase (d) Telophase

13. The kinetochore divides into two during:
(a) Early prophase (b) Late prophase
(c) Metaphase [✓ (d) Anaphase]

14. During cell division, chromosomes come to equator at:
(CPMT 2003)
(a) Prophase [✓ (b) Metaphase]
(c) Anaphase (d) Telophase

15. What plant material is best suited for studying mitosis in class room? (CBSE 2002)
[✓ (a) Anther] (b) Piece of cork
[✓ (c) Root tips] (d) Shoot apex

*16. Interzonal fibres occur in:
(a) Early metaphase (b) Anaphase
(c) Prophase (d) None of these

17. How many equational divisions are necessary in a cell of onion root tip to form 128 cells?
(DPMT 1992; CBSE 1997; AFMC 2002)
(a) 64 (b) 128
(c) 7 (d) None of these

18. Before division of cell, amount of DNA in it:
(HPPMT 2000)
(a) Halves (b) Remains same
[✓ (c) Doubles] (d) Slightly decreases

19. During mitotic cell division:
(a) No. of chromosomes is halved
[✓ (b) Chromosome no. remains the same]
(c) Chromosome no. doubles
(d) None of the above

20. Correct sequence of cell cycle is:
(CPMT 2000, 2001, 2002; Orissa JEE 2003)
(a) SG_1G_2M (b) SMG_1G_2
[✓ (c) G_1SG_2M] (d) MG_1G_2S

*21. Most active phase in cell division is:
[✓ (a) Prophase] [✓ (b) Anaphase]
(c) Metaphase (d) Telophase

22. Shortest of mitotic phase is:
(a) Telophase (b) Metaphase
(c) Prophase [✓ (d) Anaphase]

23. Amitosis is: (CPMT 1992)
(a) Cleavage of nucleus without recognizable chromosomes
(b) Division in which chromosomes are unequally distributed
(c) A division in which chromosome bridges are formed
(d) Spindles are formed

24. Exact similarities in chromosomes of various cells within the same tissue of plants is due to process of:
(a) Segregation (b) Mitosis
(c) Meiosis (d) Fertilization

*25. Anastral mitosis is a feature of:
[✓ (a) Higher animals] (b) All living organisms
(c) Lower animals [✓ (d) Higher plants]

26. Synthesis of RNA and proteins occurs at which phase of cell cycle? (CPMT 1993)
[✓ (a) G_1] [✓ (b) G_2]
(c) S (d) None of these

27. Preparation for cell division occurs in which phase?
(a) G_1-phase [✓ (b) G_2-phase] (c) S-phase (d) M-phase

28. Cell undergoes mitosis without interruption, when it has entered:
(a) S-phase
[✓ (b) G_2-phase]
(c) At any time during division
(d) G_1-phase

*29. Phragmoplast is related to:
(a) Cell elongation [✓ (b) Cytokinesis]
(c) Karyokinesis (d) None of these

*30. Mitosis was first reported by:
(a) Farmer and Moore (b) Strasburger
(c) W. Flemming (d) None of these

31. Spindle is formed at:
(a) Early prophase (b) Late prophase
(c) Late metaphase (d) Anaphase

32. Movement of sister-chromatids towards poles is due to:
(a) Repulsion between centromeres
(b) Contraction of spindle fibres
(c) Expansion of interzonal fibres
(d) All of the above

33. Period of active mitosis ranges from: (AFMC 1995)
(a) 10 minutes to few hours (b) A few hours to one day
(c) One day to a week (d) Less than a minute

34. Who coined the term meiosis?
(a) Flemming (b) Altmann
(c) Farmer and Moore (d) None of these

35. Characteristic 'Bouquet formation' occurs at which sub-stage of meiosis?
(a) Leptotene (b) Zygotene
(c) Pachytene (d) Diplotene

36. Synapsis of homologous chromosomes starts at:
(a) Centromere (b) Telomere
(c) At any point (d) None of these

37. The separation of chromosomes (bivalents) starts at:
(a) Ends (b) Pry. constriction
(c) Sec. constriction (d) At any point

38. Synaptonemal complex (SC) was first observed by:
(a) Flemming (b) Moses
(c) Strasburger (d) None of these

39. Synaptonemal complex is more conspicuous at:
(a) Zygotene [✓ (b) Pachytene]
(c) Diplotene (d) Leptotene

40. Synaptonemal complex is a:
(a) Bipartite protein framework
(b) Tripartite lipid framework
[✓ (c) Tripartite protein framework]
(d) None of the above

41. Synapsis occurs at: (BHU 1991; CPMT 1993; Raj. PMT 2001)
(a) Leptotene [✓ (b) Zygotene]
(c) Pachytene (d) Diplotene

42. Longest phase of meiosis is: [BCECE (P.T. Exam.) 2002]
[✓ (a) Prophase I] (b) Prophase II
(c) Metaphase (d) Anaphase

43. Meiosis is significant because:
(a) Restores original no. of chromosomes
(b) Produces identical cells
(c) Occurs only in somatic cells
(d) Leads to formation of gametes

44. In which of the following stages, chromosomes are like long, thin threads with beaded appearance? (CBSE 1997)
[✓ (a) Leptotene] (b) Pachytene
(c) Diplotene (d) Zygotene

45. During Anaphase I:
(a) Bivalents divide transversely
[✓ (b) Bivalents move towards poles]
(c) Chromatids separate out
(d) Tetravalents are formed

46. Exchange of chromosome segments between maternal and paternal chromatids during meiosis is called:
(a) Epistasis (b) Linkage
(c) Crossing over (d) Karyokinesis

47. During meiosis, crossing over (Genetic recombination) takes place at: (Orissa JEE 2003)
(a) Diplotene (b) Leptotene
(c) Diakinesis [✓ (d) Pachytene]

48. In *Saccharomyces*, meiosis occurs in:
(a) Ascospore [✓ (b) Ascus]
(c) Zygote (d) Pseudomycelium

*49. PMC (pollen mother cell) is the best structure to show:
(a) Chromosome elongation [✓ (b) Chiasmata]
(c) Cell fusion (d) Centrosomes

50. Separation of homologous chromosomes (Terminalization) starts in which sub-stage of meiosis I?
(a) Leptotene (b) Zygotene
(c) Pachytene [✓ (d) Diplotene]

51. The type of cell division by which the chromosome number is reduced to half is called?
(a) Mitosis (b) Amitosis
[✓ (c) Meiosis] (d) Cytokinesis

52. Every cell capable of division passes through a cycle, which is called as:
(a) Mitotic cycle (b) Krebs' cycle
(c) Meiotic cycle [✓ (d) Cell cycle]

53. Second division of meiosis is a division:
[✓ (a) Equational] (b) Reduction
(c) Equilateral (d) None of these

54. The point of attachment of two sister chromatids is called:
[✓ (a) Centromere] (b) Sec. constriction
(c) Centriole (d) None of these

55. The cell cycle of somatic cell consists of:
[✓ (a) Long interphase followed by short mitotic phase]
(b) Short interphase and long mitotic phase
(c) Long interphase and long mitotic phase
(d) Short interphase

56. In meiosis, 4 daughter cells are formed by two successive divisions in which:
(a) Both divisions are equational
(b) Both are reductional
(c) First is equational and second is reductional
(d) First is reductional and second is equational

57. Correct sequence of different substages of prophase I of meiosis is:
[✓ (a) Leptotene, zygotene, pachytene, diplotene, diakinesis]
(b) Zygotene, leptotene, diplotene, pachytene, diakinesis
(c) Leptotene, pachytene, zygotene, diplotene, diakinesis
(d) Leptotene, diplotene, pachytene, diakinesis, zygotene

58. Two daughter cells formed as a result of mitotic division are having:
(a) Half the amount of DNA
(b) Same amount of DNA and different sets of chromosomes from the parent
[✓ (c) Same amount of DNA and same set of chromosomes as the parent cell]
(d) None of the above

59. Synaptonemal complex first appears in:
(a) Zygotene (b) Pachytene
(c) Diplotene (d) Diakinesis

60. A tripartite ribbon like structure present between pairing homologous chromosomes is called:
(a) Lateral elements (b) Axial filaments
(c) Synaptonemal complex (d) Central elements

61. The second meiotic division is known as:
(a) Homotypic division (b) Heterotypic division
(c) Proleptotene (d) Zygotene

62. At which stage is chromosome morphology best studied in an organism?
(a) Meiotic metaphase I (b) Meiotic metaphase II
(c) Mitotic metaphase (d) Mitotic anaphase

63. Crossing over occurs at: **(JIPMER 2002)**
(a) 2-stranded stage (b) 4-stranded stage
(c) 3-stranded stage (d) 1-stranded stage

64. Synapsis is the pairing of:
(a) Analogous chromosomes
(b) Homologous chromosomes
(c) Non-homologous chromosomes
(d) Acentric chromosomes

65. Synaptonemal complex is a structure of:
(a) Cytokinesis
(b) Terminalization of chiasmata
(c) Chromosomal disjunction
(d) Chromosomal pairing

***66.** During meiosis reduction of chromosome number into half takes place in which of the following stages?
(a) Prophase I (b) Anaphase I
(c) Metaphase I (d) Metaphase II

67. In angiosperms, meiosis occurs at the time of:
(a) Bud formation
(b) Formation of male and female gamete
(c) Pollen grains or microspore formation
(d) Seed germination

68. During synapsis the number of threads (chromonemata) in each chromosome is:
(a) 5 (b) 8
(c) 4 (d) Many

69. Meiosis involves:
(a) One division of nucleus and one division of chromosomes
(b) One division of nucleus and two divisions of chromosomes
(c) Two divisions of nucleus and two divisions of chromosomes
(d) Two divisions of nucleus and one division of chromosomes

70. How many meiotic divisions should take place to produce 100 pollen grains?
(a) 25 (b) 50
(c) 99 (d) 100

***71.** Crossing over is advantageous because it brings about: **(MPPMT 1992)**
(a) Variation (b) Linkage
(c) Inbreeding (d) Stability

72. Movement of chromosomes is:
(a) Independent of spindle fibres
(b) Dependent on association of spindle fibres with kinetochore
(c) Due to cytoplasmic streaming
(d) Due to excess of ATP generated by mitochondria

73. Which statement is not true for meiosis?
(a) It occurs in reproductive tissues only
(b) Chromosomes undergo pairing in early prophase
(c) Chromosomes do not exchange parts
(d) Centromeres do not divide during anaphase I

74. The shape of the chromosome could be easily observed during:
(a) Prophase (b) Metaphase
(c) Anaphase (d) Telophase

75. The cross-shaped configurations formed when non-sister chromatids of a bivalent or multivalent remain in contact during the first meiotic division are known as: **(MPPMT 1992)**
(a) Chromomere (b) Bivalents
(c) Chiasmata (d) Centromeres

76. In a plant with a haploid number 10, how many chromosomes are present in anaphase of first meiotic division:
(a) 20 (b) 10
(c) 5 (d) 30

77. How many chromosomes are present in metaphase of second meiotic division of above plant?
(a) 20 (b) 10
(c) 5 (d) 30

78. How many pollen grains will be produced from 100 pollen mother cells?
(a) 100 (b) 200
(c) 400 (d) 50

79. In meiosis, haploid condition is realised by which stage?
(a) Anaphase I (b) Anaphase II
(c) Metaphase I (d) Metaphase II

80. Somatic cells multiply by:
(a) Mitosis (b) Meiosis
(c) Free cell formation (d) Amitosis

81. The region of the attachment of chromosomes to spindle fibres is called:
(a) Kinetochore (b) Centriole
(c) Sec. constriction (d) Satellite

82. A somatic cell:
(a) Cannot undergo division
(b) Can undergo mitosis but not meiosis
(c) Can undergo mitosis or meiosis
(d) Can undergo meiosis but not mitosis

83. The role of mitosis in the life history of an organism is:
(a) Reproduction in unicellular organisms
(b) Growth in multicellular organisms
(c) Repair of injured tissues
(d) All of the above

84. Mitotic spindle fibres are made of:
(a) Actin protein (b) Myosin
(c) Tubulin (d) Flagellin

85. In meiosis, the chromatids separate during: (CBSE 1990)
(a) Anaphase I (b) Metaphase I
[✓ (c) Anaphase II] (d) Metaphase II

***86.** Chromosomes begin to uncoil in which stage of mitosis?
(a) Prophase (b) Metaphase
(c) Anaphase [✓ (d) Telophase]

87. In which stage of mitosis, nucleus is active but chromosomes are not distinct?
(a) Prophase (b) Metaphase
(c) Interphase (d) Telophase

88. Homologous chromosomes undergo pairing at zygotene of meiosis. They also remain paired in salivary glands of *Drosophila*. This pairing in salivary glands resembles meiotic pairing only in which of the following respects? (CBSE 1993)
(a) The pairing can take place between non-homologous regions also
(b) The pairing takes place strictly in homologous segments
(c) The pairing is followed by crossing over
(d) The pairing is followed by reductional separation of homologous chromosomes

89. Histone proteins are synthesized in:
(a) M-phase [✓ (b) S-phase]
[✓ (c) G_1-phase] (d) G_2-phase

90. When does the synthesis of RNA stop in cell cycle?
(a) G_1-phase [✓ (b) G_2-phase]
(c) S-phase [✓ (d) M-phase]

91. Which is the shortest phase in cell cycle?
(a) G_1 (b) G_2
(c) S [✓ (d) M]

92. The role of mitosis is not merely to divide a cell into two daughter cells, but to ensure genetic continuity from one cell generation to another cell generation. The mechanism ensuring genetic continuity is:
(a) Formation of cells with new chromosomes
(b) Formation of two daughter cells
(c) Formation of two cells with identical DNA
(d) Having the chromosome number between the two new cells

93. Which of the following is not a divisional state?
(a) Interphase (b) Prophase
(c) Metaphase (d) Telophase

94. The chromatids are twisted during early prophase of mitosis by:
(a) Somatic coiling
(b) Minor coiling
(c) Plectonemic coiling
(d) Paranemic coiling

***95.** Spindle fibres are composed of:
(a) Lipids (b) Proteins
(c) Pectins (d) Cellulose

96. The spindle fibres arise from:
(a) Centriole (b) Centromere
(c) Nucleus (d) Mitochondria

97. At anaphase each chromosome contains:
(a) One DNA (b) Two DNA
(c) Three DNA (d) Four DNA

98. The difference in the division of a plant cell and animal cell is in:
(a) Spindle formation
(b) Cell plate formation
(c) Movement of chromosome from equatorial plate
(d) Coiling of chromosomes

***99.** Equal distribution of extranuclear substance of a cell is brought about by:
[✓ (a) Cytokinesis] (b) Karyokinesis
(c) Amitosis (d) All of these

100. Mitosis can occur in:
(a) Haploid cells only (b) Diploid cells only
(c) Both (a) and (b) (d) Pollen mother cells

***101.** When DNA and chromosome replicate without the division of nucleus, such a change is known as:
[✓ (a) Endomitosis] (b) Allopolyploidy
(c) Linkage (d) Crossing over

102. In cancer cells: (BHU 2003)
(a) Cell division stops
(b) Meiosis takes place
(c) Mitosis takes place
(d) Sometimes mitosis and sometimes meiosis takes place

***103.** Colchicine interferes in:
(a) Chromosome condensation
(b) DNA replication
[✓ (c) Organization and orientation of spindle elements]
(d) None of the above

***104.** C-Mitosis is:
[✓ (a) Abnormal mitosis in colchicine treated cells]
(b) Mitosis in collenchyma
(c) Mitosis having circular spindle
(d) Division of circular DNA

105. Cell division or mitosis is a normal process in a living, but sudden and abnormal mitosis in an organ will frequently result in:
(a) Zygote (b) Cancer
(c) New organ (d) Gastrula

106. A cell undergoing meiosis is known as:
(a) Androcyte (b) Zygote
(c) Meiocyte (d) Zoospore

107. Number of chromosomes after I phase of meiotic division in reduction division: (CPMT 1992)
(a) Remains unchanged (b) Becomes doubled
(c) Becomes halved (d) None of these

108. In angiosperms meiosis takes place in: (BHU 1992)
(a) Apical meristem (b) Intercalary meristem
(c) Spore mother cell (d) Endosperm

109. At which of the following stages the chromosome exhibits a beaded appearance?
[✓ (a) Leptotene] (b) Prophase II
(c) Diplotene (d) Metaphase II

110. Meiosis in higher plants can be studied in: (CPMT 1991; B.V. Pune 2003)
(a) Another cell wall (b) Microspore
[✓ (c) Microspore mother cell] (d) Megaspore

111. Zygotic meiosis is the feature of:
(a) Capsella (b) *Chlamydomonas*
(c) Fern (d) Angiosperms

112. Which is the longest period in the prophase of meiosis?
(a) Leptotene (b) Pachytene
(c) Diplotene (d) Zygotene

113. Formation of bivalents during meiosis occurs at:
(a) Leptotene (b) Pachytene
(c) Zygotene (d) Diplotene

114. Homologous chromosomes:
(a) Are from different mating parents
(b) Are from same parent
(c) Form pair during mitosis
(d) Exhibit cross over at anaphase

115. Chromosomes at pachytene appear to be: **(CBSE 1992)**
(a) Clear bivalent (b) Clear tetravalent
(c) Unclear monovalent (d) Unclear bivalent

116. Continuous variations are attributed to:
(a) Chromosomal aberrations
(b) Polyploidy
(c) Mutations
(d) Crossing over

117. In meiosis chiasmata formation takes place at:
(CPMT 1991; MPPMT 2002)
(a) Zygotene (b) Pachytene
(c) Diakinesis (d) Diplotene

118. Chiasmata were first discovered by: **(DPMT 1990)**
(a) Morgan in *Drosophila*
(b) Beadle in *Neurospora*
(c) Janssen in Amphibians
(d) Hammerling in *Acetabularia*

119. During meiosis Chiasmata are observed at:
(a) Leptotene (b) Pachytene
(c) Diplotene (d) Diakinesis

120. DNA duplication occurs in:
(a) Mitosis only (b) Meiosis only
(c) Meiosis I and mitosis (d) Meiosis II and mitosis

121. Number of chromatids in a chromosome at metaphase is:
(CBSE 1992)
(a) 2 in mitosis and 1 in meiosis
(b) 1 in mitosis and 2 in meiosis
(c) 2 each in mitosis and meiosis
(d) 2 in mitosis and 4 in meiosis

122. Minimum number of chiasmata in a bivalent is:
(a) 1 (b) 2
(c) 3 (d) 4

123. At which stage of meiosis, the bivalents become far apart, chromosomes achieve maximum condensation and nuclear membrane as well as nucleolus disappear?
(Raj. PMT 1990)
(a) Zygotene (b) Diplotene
(c) Pachytene (d) Diakinesis

124. In meiosis I, the centromere: **(Raj. PMT 1992)**
(a) Divides between metaphase and anaphase
(b) Divides between anaphase and interphase
(c) Divides but daughter chromosomes do not separate
(d) Does not divide at all

125. In meiosis, homologous chromosomes separate from one another in:
(a) Metaphase I (b) Metaphase II
(c) Anaphase I (d) Anaphase II

126. Daughter cells formed as a result of meiosis are not similar to that of the parent cell because:
(a) Crossing over occurs and number of chromosomes becomes half
(b) Prophase is large
(c) There are two divisions
(d) Synapsis occurs

127. Which of the following occurs only during meiosis?
(a) Pairing of homologous chromosomes
(b) Separation of duplicated strands
(c) Cytokinesis
(d) Disappearance of nucleolus

128. Cell division is initiated by: **(CPMT 1992)**
(a) Nucleus (b) Auxin
(c) Cytokinin (d) Ethylene

129. In second meiotic division, anaphase is characterized by:
(CPMT 1993)
(a) Separation of homologous chromosomes
(b) Separation of non-homologous chromosomes
(c) Separation of chromatids
(d) All of the above

130. Meiosis in a plant occurs when there is a change:
(a) From gametophyte to sporophyte
(b) From sporophyte to gametophyte
(c) From gametophyte to gametophyte
(d) From sporophyte to sporophyte

***131.** If one cell has twice as much DNA as another similar cell, the most probable is that:
(a) It is secreting (b) It is dividing
(c) It is respiring (d) It is moving

132. The decision for cell division occurs at:
(a) Beginning of M-phase (b) S-stage
(c) G_1-stage (d) G_2-stage

133. What important metabolic reactions occur in the interphase between two consecutive mitotic divisions?
(a) Replication of DNA (b) Replication of RNA
(c) Transformation of RNA (d) Transformation of DNA

***134.** In karyokinesis the chromosomes exhibit a minimum coiling at:
(a) Prophase (b) Metaphase
(c) Anaphase (d) Telophase

135. Disappearance of nucleolus at prophase and its appearance at telophase happens by:
(a) 18 S and 30 S ribosomes (b) 25 S and 30 S ribosomes
(c) 50 S and 30 S ribosomes (d) 60 S and 40 S ribosomes

136. Chromosomes are not involved in:
(a) Mitosis (b) Meiosis
(c) Cytokinesis (d) Amitosis

137. One of the cell organelle plays an important role in cell division, it is:
(a) Sphaerosome
(b) Centromere
(c) Nuclear membrane and Golgi body
(d) Centrosome

*138. The spindle microtubules are polar; the orientation is:
(a) (+) ends towards the poles
(b) (–) ends towards the poles
(c) (+) and (–) both at the equator
(d) (+) and (–) both at the poles

139. Division of chromosomes without the division of nucleus is called:
(a) Amitosis (b) C-mitosis
(c) Endomitosis (d) Karyokinesis

140. A karyokinesis in which the nuclear membrane persists throughout the division cycle is called: (CPMT 1991)
(a) Mitosis (b) Amitosis
(c) Meiosis (d) Fission

*141. A nucleus which involves duplication of chromosomes but fails to divide is called:
(a) Restitution nucleus (b) Macronucleus
(c) Micronucleus (d) Endomitotic nucleus

142. How many times will mitotic division take place to produce 512 cells from a single parent cell?
(a) 9 (b) 256
(c) 158 (d) 150

143. When a cell with 40 chromosomes undergoes meiosis, each of the 4 resulting cells has:
(a) 20 chromosomes (b) 40 chromosomes
(c) 80 chromosomes (d) 10 chromosomes

144. The two nuclei which are formed after completion of first meiotic cycle are:
(a) Genetically similar
(b) Genetically dissimilar
(c) May be similar and dissimilar
(d) Rarely dissimilar

145. The product of meiosis are four nuclei which are not genetically identical because of: (CBSE 1990)
(a) Crossing over
(b) Random assortment of maternal and paternal chromosomes
(c) Both (a) and (b)
(d) Nuclear division

*146. The number of chromosome pairs at diakinesis in a meiocyte is 12, the chromosome number expected in each nucleus after first and second cycle of division could respectively be: (DPMT 1990)
(a) 12 and 6 (b) 12 and 12
(c) 6 and 12 (d) 24 and 12

147. The point of attachment of two non-sister chromatids of homologous chromosomes is called:
(a) Centromere (b) Chiasma
(c) Pry. constriction (d) Sec. constriction

148. How many chromatids are present in pachytene chromosomes? (DPMT 1990)
(a) 1 (b) 2
(c) 4 (d) 8

149. Mitosis and meiosis do not occur in:
(a) Algae (b) Fungi
(c) Bryophyta (d) Monera

150. Meiosis in pteridophytes occurs when:
(a) Spores are formed (b) Gametes are formed
(c) Sex organs are formed (d) Prothallus is formed

151. Meiosis is a type of cell division where chromosomes undergo:
(a) Individual division (b) Segregation
(c) Duplication (d) Coiling

152. 'Disjunction' refers to: (MPPMT 1990)
(a) The separation of homologous chromosomes at anaphase I
(b) The type of chromosomal aberration in which there is loss of a part of a chromosome
(c) Incompatibility in fungi and the other thallophytes
(d) Modification of gene action by a non-allelic gene

153. Disjunction (segregation of homologous chromosomes) occurs at: (Raj. PMT 1992)
(a) Diplotene/prophase (b) Diakinesis/anaphase II
(c) Metaphase I (d) Anaphase I

154. Chromosomes can be counted at: (BHU 1991)
(a) Prophase (b) Metaphase
(c) Anaphase (d) Telophase

155. For the formation of 160 pollens, how many meiotic divisions are required? (Re. Ex. CPMT 1991)
(a) 20 (b) 30
(c) 40 (d) 80

156. In a cell that is not dividing the chromosomes are visible as a tangle of fine threads called: (MPPMT 1993)
(a) Microtubules (b) Chromatin
(c) Microfilaments (d) Nucleotin

157. In an organism, if the normal diploid number of chromosomes is 8, how many chromatids are present in each daughter cell at the end of meiosis? (MPPMT 1993)
(a) 2 (b) 4
(c) 8 (d) 16

158. Which of the following represents the best stage to view the shape, size and number of chromosomes? (CBSE 1994)
(a) Interphase (b) Telophase
(c) Prophase (d) Metaphase

159. Which statement best explains the evolutionary advantage of meiosis? (CBSE 1994)
(a) Meiosis alternates with mitosis from generation to generation
(b) The same genetic system is passed on from generation to generation
(c) Meiosis is necessary for sexual reproduction
(d) Genetic recombinations are possible from generation to generation

*160. Centromere is required for: (CBSE 1994)
(a) Poleward movement of chromosomes
(b) Cytoplasmic cleavage
(c) Replication of DNA
(d) Chromosome segregation

161. As a result of meiosis the four cells are produced, these are: (CPMT 1994)
(a) 75% paternal, 25% maternal
(b) 50% paternal, 50% maternal
(c) All identical
(d) All different

162. The replication of centrioles occurs during:- (MPPMT 1994)
(a) Early prophase (b) Late prophase
(c) Late telophase (d) Interphase

163. During the first metaphase of meiosis, the centromeres: (MPPMT 1994)
(a) Undergo division
(b) Do not divide
(c) Divide but do not separate
(d) Are not identical

164. The significance of meiosis lies in: (MPPMT 1995)
(a) Reduction of the diploid number of chromosomes to haploid
(b) Maintaining constancy in the number of chromosomes during sexual reproduction
(c) Production of genetic variability in the population of a species
(d) All of the above

165. The number of chromosome groups at the equatorial plate in metaphase I of meiosis in a plant with $2n=50$ will be: (MPPMT 1995)
(a) 50 (b) 25
(c) 30 (d) 100

166. The stage of mitosis in which nucleolus and nuclear membrane disappear and chromosomes become distinct is: (AFMC 1996)
(a) Prophase (b) Anaphase
(c) Telophase (d) Interphase

167. How many pollen grains will be formed after meiotic division in ten microspore mother cells? (CBSE 1996)
(a) 10 (b) 20
(c) 40 (d) 80

168. The exchange of genetic material between chromatids of paired homologous chromosomes during first meiosis division is called: (CBSE 1996)
(a) Chiasmata (b) Crossing over
(c) Synapsis (d) Transformation

169. When, during the meiotic division, do the centromeres divide? (MPPMT 1996, 97)
(a) Diplotene (b) Metaphase I
(c) Pachytene (d) Anaphase II

170. The site of meiotic division in higher plants is: (MPPMT 1996)
(a) Vegetative buds (b) Root tip cells
(c) Stomatal cells (d) Spore mother cells

171. In *Neurospora crassa*, 8 ascospores are formed instead of 4, this is by: (BHU 1993)
(a) One meiosis
(b) Two meiosis
(c) Two mitosis
(d) Meiosis followed by mitosis

172. In *Neurospora*, 8 ascospores are formed, they are $2a$, $4A$, $2a$; it shows: (CBSE 1992)
(a) First generational division
(b) Second generational division
(c) No crossing over
(d) Some meiosis occurs

173. The evidence that crossing over occurs at 4-stranded stage (and not at 2-stranded stage) comes from:
(a) 4 : 4 arrangement of ascospores in *Neurospora*
(b) Arrangement of ascospores in *Neurospora* shows 2 : 2 : 2 : 2 arrangement
(c) Meiosis studies in maize
(d) Linkage studies in *Drosophila*

174. The diploid nucleus of the ascus of *Neurospora* undergoes a meiosis followed by mitosis. This yields 8 spores, what percentage of them are recombinants?
(a) 100% (b) 75%
(c) 50% (d) 25%

175. Amphiastral or astral mitosis is observed:
(a) Only in lower animals
(b) Only in plant cells
(c) Both in plant and animal cells
(d) In animals as well as some lower plants

176. Organisms reproducing by sexual reproduction provide what amount of their genes to their progeny?
(a) All
(b) Half
(c) 1/4th
(d) Twice the number of their genes

177. A plant having 6 chromosomes in mature sex cell will be having how many chromosomes in its root cells?
(a) 3 (b) 6
(c) 12 (d) 18

178. In *Funaria* (Moss), meiosis occurs in:
(a) Spore mother cells in capsule
(b) In archegonium
(c) In antheridium
(d) In foot

179. Another name of gametic meiosis is:
(a) Terminal meiosis (b) Initial meiosis
(c) Intermediate meiosis (d) Haplontic meiosis

180. Intermediate meiosis occurs in:
(a) Most animals and some plants
(b) In all higher plants and some lower plants
(c) Never in plants
(d) In prokaryotes

181. Meiosis in *Rhizopus* (Bread mould) occurs:
(a) In zygospore during germination
(b) In sporangium during formation of sporangiospores
(c) In stoloniferous hyphae
(d) Place not known

182. Second division during the formation of 8 ascospores in ascomycetes fungi is sometimes called:
(a) Endomitosis (b) Endomeiosis
(c) Brachymeiosis (d) Heterotypic meiosis

183. Budding, a type of cell division, is common in:
(a) Rhizopus (b) Higher plants
(c) *Saccharomyces* (d) Algae

184. A type of cell division commonly found in old higher plant cells, which are about to disintegrate, is:
(a) Budding (b) Amitosis
(c) Free cell formation (d) Endomitosis

185. Free cell formation is characteristic of:
(a) Yeast
(b) Endosperm tissue
(c) Embryos of gymnosperms
(d) Both (b) and (c)

186. Movement of chiasma towards the ends of the chromosomes is called:
(a) Synapsis (b) Crossing over
(c) Disjunction (d) Terminalization

187. During telophase of mitotic division:
(a) Nucleolus appears
(b) Nuclear envelope is formed
(c) Aster rays disappear
(d) All of the above

188. Synaptonemal complex (SC) is associated with:
(a) Lampbrush chromosomes
(b) Polytene chromosomes
(c) Mitotic chromosomes
(d) Paired meiotic chromosomes

189. In plant cells, cytokinesis occurs by:
(a) Cell plate method (b) Cell furrow method
(c) Both (a) and (b) (d) None of these

190. Cell plate is formed of smaller units called:
(a) Deutoplasm (b) Phragmoplasts
(c) Asters (d) None of these

191. Cell division can be temporarily ceased by:
(a) Colchicine treatment (b) Cytokinins
(c) High temperature (d) All of these

***192.** Which of the following is associated with principal mechanism of asexual reproduction and vegetative propagation?
(a) Mitosis (b) Meiosis
(c) Both (a) and (b) (d) None of these

193. The cells undergo mitosis, when:
(a) Ratio of RNA to DNA is high
(b) Ratio of DNA to RNA is high
(c) Ratio of RNA to DNA is low
(d) None of the above

194. Which of the following processes plays an important role in speciation and evolution?
(a) Mitosis (b) Meiosis
(c) Amitosis (d) None of these

195. Correct sequence of different stages of mitosis is:
(a) Metaphase, prophase, anaphase, telophase
(b) Prophase, metaphase, anaphase, telophase
(c) Anaphase, prophase, metaphase, telophase
(d) Telophase, anaphase, metaphase, prophase

196. Time span between two successive mitotic divisions is called:
(a) Interphase (b) Synthetic phase
(c) Telophase (d) Restitution phase

197. Which is called 'Mitotic poison'?
(a) Pyrethrum (b) Rotenone
(c) Colchicine (d) Aflatoxin

198. Which of the following chemicals cause uncontrolled increase in cell division and cell size leading to tumour formation?
(a) Aflatoxin (b) Benzpyrene
(c) Mustard gas vapours (d) All of these

Match the following (Q. 199-201)

199. I Metaphase
II Interphase
III Telophase
IV Prophase
A. Longitudinal splitting of chromosomes
B. Spindle breaks down and membrane is reformed
C. Chromosomes arranged at equatorial plate
D. The period between two cell divisions
(a) I-A, II-B, III-C, IV-D (b) I-B, II-C, III-D, IV-A
(c) I-C, II-D, III-B, IV-A (d) I-C, II-B, III-D, IV-A

200. I Cytokinesis
II Karyokinesis
III Prophase
IV Mitosis
A. Cytoplasmic division
B. Nuclear division
C. Chromosome shortens and thickens
D. Somatic division
(a) I-D, II-B, III-C, IV-A (b) I-A, II-B, III-C, IV-D
(c) I-A, II-C, III-D, IV-B (d) I-A, II-B, III-D, IV-C

201. I Zygotene II Pachytene
III Diplotene IV Diakinesis
A. Crossing over
B. Pairing of homologous chromosomes
C. Disappearance of nucleolus and nuclear membrane
D. Beginning of separation of paired chromosomes
(a) I-A, II-B, III-C, IV-D (b) I-B, II-A, III-D, IV-C
(c) I-B, II-A, III-C, IV-D (d) I-A, II-D, III-B, IV-C

202. Which of the following structures will not be common to mitotic cell of a higher plant? **(CBSE 1997)**
(a) Cell plate (b) Centromere
(c) Centriole (d) Spindle fibres

203. In meiosis, the daughter cells differ from parents cells as well as amongst themselves due to: **(CBSE 1991)**
(a) Segregation, independent assortment and crossing over
(b) Segregation and crossing over
(c) Independent assortment and crossing over
(d) Segregation and independent assortment

204. Meiosis II performs: **(CBSE 1993)**
(a) Separation of sex chromosomes
(b) Synthesis of DNA and centromere
(c) Separation of homologous chromosomes
(d) Separation of chromatids

205. Meiosis occurs in tomato in: **(Rohtak PMT 1994)**
(a) Pollen sac and ovule
(b) Microspore and megaspore mother cell
(c) Both (a) and (b)
(d) Zygote

206. Mitosis is absent in: **(Raj. PMT 1995)**
(a) Zygote (b) Germinal cell
(c) Bone cell (d) None of these

207. In a plant cell cytokinesis begins at:

(a) Anaphase (b) Telophase

(c) G_0-phase (d) Interphase

208. Duration or time for a mitotic division in an organism is:

(a) Variable (b) Constant

(c) Varies in different tissues(d) None of these

*209. Somatic divisions can be observed in:

(a) Flower (b) Leaf

(c) Stem tip (d) Stem and root tip both

210. Which of the following induce cell division in a cell? (AFMC 1997)

(a) Cytokinin (b) Gibberelins

(c) Auxins (d) ABA

211. RNA and protein synthesis occur in which stage of interphase? (MPPMT 1997)

(a) S-phase (b) G_1-phase

(c) G_2-phase (d) Both G_1 and G_2-phases

212. In which state, synapsis of chromonemata of chromosome initiates? (MPPMT 1997)

(a) Zygotene (b) Leptotene

(c) Pachytene (d) Diplotene

213. Synapsis is related with which stage? (Raj. PMT 1997)

(a) Pachytene (b) Leptotene

(c) Zygotene (d) Diplotene

214. DNA synthesis (replication) occurs in which typical stage? (CBSE 1996; CPMT 1997, 2001; Uttaranchal PMT 2001)

(a) G_1-phase (b) S-phase

(c) G_2-phase (d) M-phase

*215. Nuclear spindle has type of fibres: (MPPMT 1996)

(a) One (b) Three

(c) Two (d) Four

216. When paternal and maternal chromosomes change their materials with each other in cell division, this event is called: (CBSE 1996)

(a) Synapsis (b) Crossing over

(c) Bivalent forming (d) Dyad forming

217. During cell division in apical meristem the nuclear membrane appears in:

(a) Metaphase (b) Anaphase

(c) Telophase (d) Cytokinesis

218. Non-disjunction of chromosome occurs at: (CPMT 1997)

(a) Anaphase (b) Prophase

(c) Telophase (d) Metaphase

219. For active mitosis, we can see: (CPMT 1998)

(a) Onion root (b) Garlic root

(c) Turnip root (d) Mango root

220. Alkaloid used to arrest mitosis is obtained from: [CPMT 1999; BCECE (P.T.) Exam. 2002]

(a) *Rauwolfia* (b) *Papaver*

(c) *Colchicum* (d) *Canabis*

221. RNA and proteins are synthesized in which phase of cell cycle? (BHU 1999)

(a) G_1-phase (b) G_2-phase

(c) S-phase (d) All of these

222. At what point does spindle fibres attach to chromosome during cell division? (CBSE 2000)

(a) Kinetochore (b) Chromonema

(c) Centrosome (d) None of these

223. The sequence in prophase is: (CPMT 2000)

(a) Leptotene, Zygotene, Diplotene, Pachytene, Diakinesis

(b) Leptotene, Zygotene, Pachytene, Diplotene, Diakinesis

(c) Leptotene, Diplotene, Zygotene, Pachytene, Diakinesis

(d) Diplotene, Leptotene, Pachytene, Zygotene, Diakinesis

224. Meiosis was first of all observed by: (CPMT 2000)

(a) Farmer and Moore

(b) Winiwarter and Strasburger

(c) Whittaker

(d) Flemming

225. Amitosis is: (CPMT 2000)

(a) Common method of cell division in organism

(b) Division of cell without spindle formation

(c) Equal division of nucleus and cytoplasm

(d) None of the above

*226. Characteristic of meiosis is: (CPMT 2000)

(a) Two nuclear and two chromosome divisions

(b) Two nuclear and one chromosome divisions

(c) One nuclear and two chromosome divisions

(d) One nuclear and one chromosome divisions

227. In which mitosis does not occur? (MPPMT 2000)

(a) Green algae (b) Fungi

(c) Bacteria (d) Higher plants

228. In plant cells, cytokinesis occurs by: (MPPMT 2000)

(a) Furrowing (b) Cell plate formation

(c) Invagination (d) Anticlinal division

229. In mitosis centromere divides at: (MPPMT 2000; CPMT 2001)

(a) Metaphase (b) Anaphase

(c) Telophase (d) Both (b) and (c).

230. Which is not characteristic of mitosis? (MPPMT 2000)

(a) Leptotene (b) Zygotene

(c) Pachytene (d) All of these

231. G_1, S and G_2-stages are seen in: (MPPMT 2000)

(a) Prophase (b) Metaphase

(c) Interphase (d) Anaphase

232. In meiosis, centromere divides in: (CPMT 2001)

(a) Prophase I (b) Metaphase I

(c) Anaphase I (d) Anaphase II

*233. Colchicine arrests which of the following stage of cell division? (AIIMS 2000)

(a) Prophase (b) Anaphase

(c) Telophase (d) Metaphase

234. Spindle fibres of mitotic cells are made up of: (AIIMS 2001)

(a) Actin (b) Myosin

(c) Collagen (d) Tubulin

235. Zygotic meiosis occurs in: (AFMC 2001)

(a) Gymnosperms (b) Ferns

(c) *Chlamydomonas* (d) None of these

236. At which stage of mitosis chromatids separate and start moving towards poles? (MPPMT 2001)

(a) Prophase (b) Metaphase

(c) Anaphase (d) Telophase

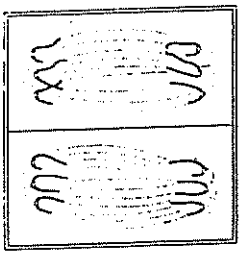
*237. The structure of chromosome can be best seen at: (BHU 2001)

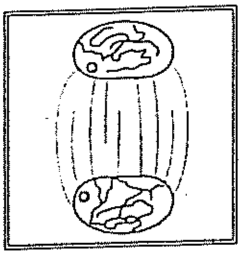
(a) Prophase (b) Metaphase

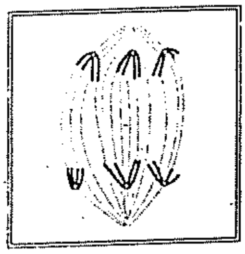
(c) Anaphase (d) Telophase

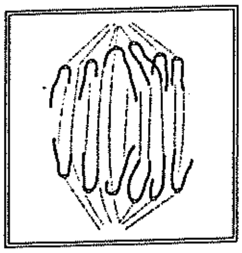
*238. The phase of cell cycle during which 'DNA polymerase' is functionally active: (CET Karnataka 2002)
(a) G_2 (b) S
(c) M (d) G_1

239. Choose the diagram which correctly shows the anaphase-I stage? (CET Karnataka 2002)


(a)


(b)


(c)


(d)

240. Diakinesis occurs in: (Raj. PMT 2001)
(a) Prophase-I of meiosis (b) Prophase-II of meiosis
(c) Metaphase-I of meiosis (d) Metaphase of mitosis

241. In pachytene stage of meiosis the chromosomes appear: (BHU 2002)
(a) Single stranded (b) Double stranded
(c) Three stranded (d) Four stranded

242. Time period between meiosis I and meiosis II is called: (AFMC 2002)
(a) Interphase (b) Interkinesis
(c) Cytokinesis (d) Anaphase I

243. Which process occurs during meiosis? (AFMC 2002)
(a) Recombination of linked genes
(b) Strengthening of linkage
(c) Doubling of chromosomes
(d) All of the above

*244. Which of the following protein forms spindle fibres? (CBSE 2002)
(a) Actin (b) Myosin
(c) Actomyosin (d) Myoglobin

245. A group of characteristics that identifies a particular chromosome set, is called:
(a) Phenotype (b) Genotype
(c) Karyotype (d) Holotype

246. Which type of karyotype is considered to be relatively advanced feature?
(a) Asymmetric (b) Symmetric
(c) Both (a) and (b) (d) None of these

247. Which is recent and very accurate technique for preparation of karyotype?
(a) Banding technique (b) FISH
(c) McFISH (d) Flow cytometry

248. Karyotype analysis represents:
(a) Evolutionary relationships
(b) Primitive or advanced features of organisms
(c) Chromosomal abnormalities
(d) All of the above

249. Mitosis occurs in: (Raj. PMT 2002)
(a) Haploid individuals (b) Diploid individuals
(c) Both (a) and (b) (d) In bacteria only

250. In which phase of nuclear division is plectonemic coiling found? (MPPMT 2002)
(a) Meiotic prophase (b) Mitotic prophase
(c) Amitotic division (d) Crossing over

251. During mitosis the number of chromosomes: (CPMT 2003)
(a) Gets changed
(b) Has no change
(c) May be changed if cell is mature
(d) May be changed if cell is immature

252. The pairing of homologous chromosomes during zygotene is called as: (BHU 2003)
(a) Synapse (b) Terminalization
(c) Synapsis (d) Crossing over

253. At which stage of mitosis chromatids separate and pass to different poles? (DPMT 2003)
(a) Prophase (b) Metaphase
(c) Anaphase (d) Telophase

254. During meiosis, crossing over occurs between: (DPMT 2003)
(a) Sister chromatids of homologous chromosome
(b) Non-sister chromatids of homologous chromosome
(c) Sister chromatids of non-homologous chromosome
(d) Non-homologous chromatids of homologous chromosome

255. Significance of meiosis lies in: (B.V. Pune 2003)
(a) Production of genetic variability
(b) Maintaining constancy of chromosome number during sexual reproduction
(c) Reduction of chromosome number to one half
(d) All of the above

ANSWERS

1—c	2—d	3—c	4—a	5—b	6—a	7—d	8—d	9—c	10—c	11—b	12—a
13—d	14—b	15—c	16—b	17—c	18—c	19—b	20—c	21—a	22—d	23—a	24—b
25—d	26—a	27—b	28—a	29—b	30—b	31—b	32—d	33—a	34—c	35—a	36—c
37—b	38—b	39—b	40—c	41—b	42—a	43—a	44—a	45—b	46—c	47—d	48—b
49—b	50—d	51—c	52—d	53—a	54—a	55—a	56—d	57—a	58—c	59—a	60—c
61—a	62—c	63—b	64—b	65—d	66—b	67—c	68—c	69—d	70—a	71—a	72—b
73—c	74—c	75—c	76—b	77—b	78—c	79—a	80—a	81—a	82—b	83—d	84—c
85—c	86—d	87—c	88—b	89—b	90—d	91—d	92—c	93—a	94—c	95—b	96—a
97—a	98—b	99—a	100—c	101—a	102—c	103—c	104—a	105—b	106—c	107—c	108—c
109—a	110—c	111—b	112—b	113—c	114—a	115—a	116—d	117—d	118—c	119—c	120—c
121—c	122—a	123—d	124—d	125—c	126—a	127—a	128—c	129—c	130—b	131—b	132—c
133—a	134—a	135—d	136—c	137—d	138—b	139—c	140—b	141—a	142—a	143—a	144—b
145—c	146—b	147—b	148—c	149—d	150—a	151—b	152—a	153—d	154—b	155—c	156—b
157—c	158—d	159—d	160—d	161—d	162—d	163—b	164—d	165—b	166—a	167—c	168—b
169—d	170—d	171—d	172—b	173—b	174—c	175—d	176—b	177—c	178—a	179—a	180—b
181—a	182—c	183—c	184—b	185—d	186—d	187—d	188—d	189—a	190—b	191—a	192—a
193—a	194—b	195—b	196—a	197—c	198—d	199—c	200—b	201—b	202—c	203—a	204—c
205—c	206—b	207—a	208—c	209—d	210—a	211—b	212—b	213—c	214—b	215—b	216—b
217—c	218—a	219—a	220—c	221—a	222—a	223—b	224—b	225—b	226—b	227—c	228—b
229—b	230—d	231—c	232—d	233—d	234—d	235—c	236—c	237—b	238—b	239—c	240—a
241—d	242—b	243—a	244—a	245—c	246—a	247—d	248—d	249—c	250—b	251—b	252—c
253—c	254—b	255—d									

33. Smallest structural unit of protein is known as:
    (a) Amino acid (b) Peptide
    (c) Peptone (d) Dipeptide
34. 'Bioplast' term for mitochondria was used by:
    (a) Altmann (b) Benda
    (c) Kollicker (d) Flemming
35. Mitochondria as place of cellular respiration was first observed by:
    (a) Kollicker (b) Hogeboom
    (c) Benda (d) Michaelis
36. Ribosomes in eukaryotic mitochondria and chloroplast are:
    (a) 70 S (b) 80 S
    (c) Both (a) and (b) (d) 60 S
37. Which provides maximum energy on oxidation?
    (a) Carbohydrate (b) Fat
    (c) Protein (d) Vitamin
38. Starch is polymer of:
    (a) Fructose (b) Glucose
    (c) Maltose (d) Sucrose
39. The most abundant protein is found in:
    (a) Mitochondria (b) Chloroplasts
    (c) Liver (d) Ribosomes
40. The core of nucleosome is made of histones:
    (a) H_1, H_2A, H_2B, H_3
    (b) H_1, H_2A, H_2B, H_4
    (c) H_1, H_2A or H_2B, H_3, H_4
    (d) H_2A, H_2B, H_3, H_4
41. Isolation of individual organelles from cell homogenates is achieved through:
    (a) X-ray diffraction
    (b) Chromatography
    (c) Differential centrifugation
    (d) Spectrophotometry
42. Organism widely studied in relation to nucleo-cytoplasmic interaction is:
    (a) *Acetabularia* (b) *Aulosira*
    (c) *Anacystis* (d) *Alaria*
43. On separating the cell organelles of a living cell, which will be alive?
    (a) E.R. (b) Cell wall
    (c) Ribosome (d) Chloroplast
44. 'Heterochromatin' term was originally given by:
    (a) DuPraw (b) Darlington
    (c) Heitz (d) Strasburger
45. Meiosis involves two divisions:
    (a) First is homeotypic and second heterotypic
    (b) First is heterotypic and second homeotypic
    (c) Both homeotypic
    (d) Both heterotypic
46. Most active phase in cell division is:
    (a) Prophase (b) Metaphase I
    (c) Anaphase (d) Telophase II
47. Autolysis is related to:
    (a) Lysosomes (b) Centrosomes
    (c) Sphaerosomes (d) Phagosomes
48. The Singer-Nicolson model of plasma membrane differs from Robertson's model in:
    (a) Number of lipid layers
    (b) Arrangement of lipid layers
    (c) Arrangement of proteins
    (d) Absence of proteins in the former
49. Most common monomer of carbohydrates is:
    (a) Amino acid (b) Fructose
    (c) Glucose (d) Maltose
50. Microbodies associated with oxidation of amino acid and uric acid are:
    (a) Glyoxysomes (b) Peroxisomes
    (c) Sphaerosomes (d) None of these
51. ATP driven H-pump is present in membrane of:
    (a) Mitochondria (b) Lysosome
    (c) Golgi complex (d) All of these
52. The high energy bonds of ATP are between:
    (a) C—C (b) C—O
    (c) C—N (d) O—P
53. ATP as primary and universal carrier of chemical energy in cells, was postulated by:
    (a) Lohmann (b) Lipmann
    (c) McMann (d) Gibbs
54. Total amount of energy in the universe remains constant, represents:
    (a) First law of thermodynamics
    (b) Second law of thermodynamics
    (c) Both (a) and (b)
    (d) None of the above
55. Reactions that are thermodynamically unfavourable and cannot occur simultaneously, possessing a $+\Delta G$ value are:
    (a) Exergonic reactions (b) Endergonic reactions
    (c) Exothermic reactions (d) Endothermic reactions

ANSWERS

1—a	2—b	3—a	4—b	5—b	6—b	7—c	8—a	9—b	10—d	11—b	12—b
13—b	14—a	15—c	16—b	17—b	18—c	19—c	20—c	21—d	22—c	23—b	24—b
25—b	26—d	27—b	28—b	29—b	30—a	31—a	32—b	33—a	34—a	35—b	36—a
37—b	38—b	39—b	40—d	41—c	42—a	43—d	44—c	45—b	46—a	47—a	48—c
49—c	50—b	51—b	52—d	53—b	54—a	55—b					

UNIT-2

ASSERTION AND REASON TYPE QUESTIONS

In the questions given below, two statements—an Assertion (A) and a Reason (R) are given. Give the appropriate response as:

(*a*) *If both A and R are true and R is the correct explanation of A.*
(*b*) *If both A and R are true but R is not the correct explanation of A.*
(*c*) *If A is true but R is false.*
(*d*) *If both A and R are false.*
(*e*) *If A is false and R is true.*

1. A: Molecules of different substances present in a solution are separated by chromatography technique.
R: On the basis of differential movement of components, the separation is done by the process of chromatography.

2. A: Separation of different cell organelles can be done by the process of centrifugation.
R: Depending upon the shape, size and density, different sub-cellular components are separated in centrifugation.

3. A: Study of living cells cannot be done through electron microscope.
R: High voltage which is required to operate electron microscope kills the living materials.

4. A: Ability of a system to distinguish two close points as two separate points is called resolving power.
R: Resolving power of human eye is 100 μ.

5. A: Specific constituents within the cell are located by cytochemistry technique.
R: Colour contrasts at specific sites are produced with the help of specific dyes in the technique of cytochemistry.

6. A: The resolving power of electron microscope is 10 Å.
R: The high resolution power of electron microscope is because of very low wavelength of electron beam used as a light source.

7. A: In phase contrast microscope, living cells and tissues can be studied without fixing and staining them.
R: Electron beam is used as a source of light in phase contrast microscope.

8. A: For microscopic study of biological materials, thick sections of these materials are required.
R: Sections of material are cut by spectrophotometer.

9. A: Ruthenium red is used for staining pectin.
R: Ruthenium red is a vital dye.

10. A: Autoradiography is helpful in studying replication of chromosomes.
R: Semiconservative mode of DNA replication was studied by the technique of cytochemistry.

11. A: Viruses are an exception to cell theory.
R: Viruses are sub-cellular in nature, *i.e.*, are obligate parasites.

12. A: Bacteria and cyanobacteria are prokaryotic cells.
R: There is ill-defined or incipient nucleus or nucleus with definite nuclear membrane and nucleolus is absent in bacteria and cyanobacteria.

13. A: Single naked chromosome is present in prokaryotes.
R: Histones are altogether absent in prokaryotes.

14. A: In members of class Dinophyceae of algae, there is mesokaryotic cell organization.
R: In Dinophyceae, there is true or eukaryotic nucleus but chromosomes are not well organized as basic proteins or histones are absent.

15. A: Clear optically homogeneous fluid part of cytoplasm is called cytosol.
R: Cytosol is made of true solution in which cell organelles are embedded.

16. A: Fluid mosaic model is the famous model of structure of cell wall.
R: Lipids and extrinsic proteins form mosaic pattern in cell membrane.

17. A: The proteins which extend through the lipid bilayer in plasma-membrane are called tunnel proteins.
R: The portions of polypeptide chains that extend through lipid bilayer typically occur as α-helices.

18. A: Outer membrane of mitochondrion is specially permeable while inner membrane is highly impermeable.
R: Integral proteins called porines are present in outer membrane of mitochondria while these are absent in inner membrane.

19. A: Mitochondria are believed to be bacterial endosymbionts of cells.
R: Mitochondria arise *de novo* and these also lack nucleic acid and ribosomes.

20. A: Grana and stroma are two fractions of mitochondria.
R: Chloroplasts are associated with photosynthesis phenomenon.

21. A: Chlorophyll-a is yellowish green micro-crystalline solid soluble in organic solvents.
R: In chloroplast, chlorophyll-a is 25%.

22. A: Carotenoids are accessory pigments of chloroplast.

EXPLANATION OF SELECTED QUESTIONS (*)

8. Spindle fibres made of microtubules are responsible for chromosomal movements towards opposite poles.
16. Interzonal fibres develop between daughter centromeres formed by division of centromere of a chromosome during anaphase stage of cell division.
21. Prophase is the most active stage of cell division as different activities like appearance of chromosomes, coiling and condensation of chromosomes, longitudinal splitting of chromosomes into two chromatids, disappearance of nuclear membrane and nucleolus as well as formation of spindle apparatus occur during this stage.
25. In higher plants, there are no centrioles and hence no asters are formed. Spindle fibres are formed by some unknown mechanism.
29. Phragmoplasts or cell wall vesicles are provided by Golgi-complex, which unite together to form cell plate and hence cell wall (cytokinesis).
30. Mitosis was first reported or observed in plants by E. Strasburger (1875).
49. Chiasmata are the points where crossing over occurs during meiosis and meiosis can be best observed in PMC.
66. In Anaphase I of meiosis, the chromosomes of bivalents move towards opposite poles, which then leads to reduction in chromosome number to half.
71. Crossing over produces recombinations of genes which lead to variations.
86. In telophase stage, the chromosomes become decondensed, fuzzy and uncoiled and convert into chromatin reticulum.
95. Spindle fibres are composed of microtubules, which in turn are made of tubulin protein (97% tubulin).
99. Division of extranuclear substance or cytoplasm is called cytokinesis.
101. Multiplication of chromosomes in nucleus without karyokinesis and cytokinesis is called endomitosis.
103. Colchicine or mitotic poison inhibits assembly and polymerisation of microtubules hence spindle is not formed.
104. C-mitosis is colchicine induced abnormal mitosis.
131. DNA content of cell is doubled before its division.
134. Chromatin of interphase thickens and condenses by spiralization or plectonemic coiling to form well defined chromosomes in prophase.
138. Spindle microtubules are polar with their polymerizing '+' end facing the centre and non-polymerising '–' end facing poles.
141. When normal mitosis occurs upto anaphase and two sets of chromosomes thus formed remain in a common nuclear membrane, such nucleus is called restitution nucleus.
146. When number of chromosome pairs or bivalents are 12, it means $2n = 24$. Hence number of chromosomes after meiosis I and meiosis II is 12 each (n).
160. Centromere or primary constriction of chromosomes is the point where spindle fibres are attached.
192. Meiosis is characteristic of organisms with sexual reproduction.
209. Stem and root tips have meristems, which have power of continuous division.
215. 3 types of spindle fibres occur in nuclear spindle of animal cell—astral (determine plane of cytokinesis), chromosomal (responsible for movement of chromosomes towards poles in anaphase, also called discontinuous fibres) and polar or continuous fibres (maintain integrity of spindle).
226. In meiosis, nucleus undergoes two divisions (first is reductional and second is equational) while chromosomes divide only once (in anaphase II).
233. By colchicine, mitosis is blocked at metaphase because of breakdown of microtubules of spindle.
237. At metaphase, the chromosomes are maximally condensed and hence their structure is clearly visible.
238. DNA polymerase enzyme is responsible for DNA replication or DNA duplication, which occurs in S-phase of cell cycle.
244. Spindle fibres are mostly made of tubulin protein but in some lower animals, spindle fibres are made of actin protein.

TEST PAPER—Unit-2

1. Which of the following is the largest cell organelle?
(a) Mitochondria (b) Ribosomes
(c) Lysosomes (d) Sphaerosomes

2. Plasma membrance (plasmalemma) is:
(a) Permeable (b) Differentially permeable
(c) Semipermeable (d) Impermeable

3. Which of the following components of cell is non-living?
(a) Cell wall (b) Cell membrane
(c) Cytoplasm (d) Nucleus

4. Plant cell ribosomes differ from bacterial ribosomes in having:
(a) Smaller size (70 S)
(b) Larger size (80 S)
(c) Differential chemical structure
(d) All of the above

5. Sphaerosomes are connected with:
(a) Protein metabolism (b) Lipid metabolism
(c) Respiration (d) Glycolate pathway

6. Lysosomes with food content are known as:
(a) Primary lysosomes (b) Secondary lysosomes
(c) Residual bodies (d) Microbodies

7. Microtubules occur in:
(a) Viruses (b) Bacteria
(c) Eucaryotic cells (d) All of these

8. The function of autophagic vacuoles is to digest:
(a) Cell organelles
(b) Solid particles of phagosomes
(c) Fluid drops of pinosomes
(d) None of the above

9. Microtubules were first observed by:
(a) Robert Brown (b) Robertis and Franchi
(c) Schwann (d) Hoffmeister

10. Which of the following is unit membrane?
(a) E.R. membrane (b) Golgi membrane
(c) Plasma membrane (d) All of these

11. A plant cell with more than two nuclei is called:
(a) Syncytial (b) Coenocyte
(c) Polynucleate (d) None of these

12. The order of sedimentation of sub-cellular structures during differential centrifugation is:
(a) Lysosome, ribosome, mitochondria, nucleus
(b) Nucleus, mitochondria, lysosome, ribosome
(c) Mitochondria, nucleus, lysosome
(d) Lysosome, mitochondria, nucleus, ribosome

13. Plant cells are connected by channels through their walls called:
(a) Desmosomes (b) Plasmodesmata
(c) Tight junctions (d) Gap junctions

14. Period of active mitosis ranges from:
(a) 10 minutes to few hours (b) Few hours to one day
(c) One day to a week (d) Less than a minute

15. The active site of an enzyme is produced by its:
(a) Primary structure (b) Secondary structure
(c) Tertiary structure (d) None of these

16. How many membranes constitute the nuclear envelope?
(a) One (b) Two
(c) Three (d) None of these

17. Structural polysaccharide of plant cells is:
(a) Starch (b) Cellulose
(c) Sucrose (d) Glucose

18. Prokaryote and eukaryote terms were given by:
(a) Nageli (b) Aristotle
(c) Chatton (d) Pasteur

19. Which is not present is a prokaryotic cell?
(a) Cell wall (b) Cell membrane
(c) Nuclear envelope (d) Ribosomes

20. Proteins utilized inside cell are synthesized in:
(a) Free ribosomes (b) Bound ribosomes
(c) Rough E.R. (d) Smooth E.R.

21. Chemical nature of cellulose is:
(a) Polypeptide (b) Polynucleotide
(c) Oligosaccharide (d) Polysaccharide

22. Number of carbon atoms present in monosaccharides is:
(a) 10–15 (b) 20
(c) 3–7 (d) 20–50

23. Instant source of cellular energy is:
(a) ATP (b) Glucose
(c) Pyruvic acid (d) NADP

24. Primary structure of protein is due to:
(a) H-bonds (b) Peptide bonds
(c) Disulphide bonds (d) Ionic bonds

25. Karyokinesis is the division of:
(a) Cytoplasm into two (b) Nucleus into two
(c) Protoplasm into two (d) None of these

26. RNA is altogether absent in:
(a) Cytoplasm (b) Ribosomes
(c) Chromosomes (d) Plasmalemma

27. Before division of cell, the amount of DNA in it:
(a) Halves (b) Doubles
(c) Remains same (d) Slightly decreases

28. Nuclear membrane disappears at:
(a) Early prophase (b) Late prophase
(c) Metaphase (d) Anaphase

29. Who stated that cell is the basic unit of all plants?
(a) Schwann (b) Schleiden
(c) Virchow (d) Swanson

30. Synaptonemal complex (SC) first appears in:
(a) Zygotene (b) Pachytene
(c) Diplotene (d) Diakinesis

31. Synthesis of RNA and proteins occurs at which phase of cell cycle?
(a) G_1 (b) G_2
(c) S (d) None of these

32. Genophore (nucleoid) consists of:
(a) A single stranded DNA
(b) A single double stranded DNA
(c) RNA and histones
(d) DNA and histones

R: Carotenes and xanthophylls protect chlorophyll against photo-oxidation and then transfer light energy to chlorophylls.

23. A: Sialic acid (special carbohydrate) is found in plasma membrane.
R: Sialic acid is synthesized in Golgi complex.

24. A: Ribosomes are known as RNP particles.
R: Ribosomes are made of r-RNA and proteins.

25. A: Peroxisomes participate in photorespiration in C-4 plants.
R: Catalase enzyme is present in high concentration in peroxisomes.

26. A: Lysosomes are called 'Suicidal bags'.
R: A large number of hydrolytic enzymes are present in lysosomes.

27. A: Basal bodies are formed from centrioles.
R: Both basal bodies and centrioles have 9 + 2 structural organization.

28. A: Microtubules are present in only prokaryotic cells.
R: Centrioles, basal bodies, flagella, cilia, spindle fibres are formed by microtubules.

29. A: Chromosomes are nucleoproteins in nature.
R: DNA, RNA, histones and non-histones are major chemical constituents of chromosomes.

30. A: All cells arise from pre-existing cells.
R: The phenomenon of production of daughter cells from parent cell is called cell division.

31. A: Development of complete organism from zygote is by means of mitosis.
R: Mitotic division is meant for multiplication of cells.

32. A: Cytokinesis is by cell plate method in plant cells.
R: Cell wall vesicles or phragmoplasts which join to form cell plate are provided by ER.

33. A: Colchicine is called mitotic poison.
R: Colchicine causes temporary cessation of mitotic division by inhibiting spindle formation.

34. A: Meiosis is associated with somatic cells.
R: Chromosome number is reduced to half by meiotic division.

35. A: Intermediate meiosis occurs in higher plants.
R: Meiosis in higher plants occurs during the formation of gametes.

36. A: Prophase II is the longest and most complex stage of meiosis.
R: 5 sub-stages occur in metaphase I of meiosis.

37. A: Synaptonemal complex (SC) is a feature of meiotic prophase I.
R: Ubiquitin is the characteristic protein of SC.

38. A: Meiosis leads to recombinations of genes.
R: Crossing over occurs in pachytene sub-stage of prophase I of meiosis.

39. A: No physical phenomenon or chemical reaction occurs without use of energy.
R: Capacity to do work is called energy.

40. A: ATP is called energy currency of cell.
R: ATP can hand over its energy to any reaction.

41. A: According to first law of thermodynamics, the total amount of energy in the universe remains constant.
R: Energy can neither be created nor destroyed but whenever it is used to do work, it is converted from one form to another.

42. A: The increase in entropy will lead to death of the living system unless the loss is made up through input of usable energy or free energy.
R: The system which has a continuous influx of energy is called open system.

43. A: For occurrence of any process in the universe, there is decrease in availability of free energy and increase in entropy.
R: A process can occur spontaneously only if the sum of entropies of the system and its surroundings decreases.

44. A: Reactions that occur spontaneously are called endergonic reactions.
R: Endergonic reactions are always having negative ΔG.

45. A: There is one high energy bond in a molecule of ATP.
R: ATP acts as a bridge between exergonic and endergonic reactions of cell.

46. A: Every electron carrier is capable of existing in either an oxidized or reduced state.
R: Each electron carrier is successively reduced by gain of electrons from the preceding carrier in chain and subsequently oxidized by loss of electrons to the next carrier.

47. A: Flavoproteins are made of a polypeptide chain which is bound tightly to FAD or FMN.
R: FAD/FMN are derived from vitamin B_2.

48. A: Coenzyme Q (CoQ) is also called ubiquinone.
R: CoQ or ubiquinone is ubiquitous in nature, *i.e.*, occurring in all cells.

49. A: Cytochromes are reddish in colour.
R: Cytochromes are proteins that contain heme group as prosthetic group.

50. A: The pathways leading to breakdown of complex substances into simple ones are called anabolic pathways.
R: Anabolic pathways provide chemical energy required for many activities of a cell.

51. A: Schleiden and Schwann were the first to observe the cells and to put forward cell theory. **(AIIMS 1994)**
R: The cells are always living units.

52. A: Cell membrane is selectively permeable.
R: The constituent molecules can freely move in the membrane. **(AIIMS 1994)**

53. A: Chromatin is the hereditary material which is transferred from generation to generation.
R: Chromatin is the common constituent of all types of nucleic acid. **(AIIMS 1995)**

54. A: Enzyme molecules have active sites on their surface and their substrates have reactive sites on their surface.
R: Active and reactive sites push the enzyme and substrate molecules away from each other. **(AIIMS 1996)**

55. A: Meiotic division results in the production of haploid cells.
R: Synapsis occurs during zygotene of meiosis. (AIIMS 1998)

56. A: Plant cell wall lacks selective permeability.
R: It allows free passage of dissolved materials through it. (AIIMS 1999)

57. A: Lysosomes help in the process of photorespiration.
R: Lysosomes have neutralizing enzymes. (AIIMS 1999)

58. A: Coenzyme is a non-protein group without which certain enzymes are inactive or incomplete.
R: Coenzymes not only provide a point of attachment of the chemical group being transformed but also influence the properties of the group. (AIIMS 1999)

59. A: DNA is associated with proteins.
R: DNA winds around histone proteins that form a pool and the entire structure is called a nucleosome. (AIIMS 2000)

60. A: Histones are basic proteins of major importance in packaging of eukaryotic DNA. DNA and histones comprise chromatin, forming the bulk of eukaryotic chromosome.
R: Histones are of five major types H_1, H_2A, H_2B, H_3 and H_4. (AIIMS 2000)

61. A: Mitochondria is known as power house of cell.
R: ATP production takes place here. (AIIMS 2001)

62. A: Starch is hydrolysed by ptyalin to maltose.
R: Sucrase hydrolyses sucrose to lactose. (AIIMS 2001)

63. A: It is important that organisms should have cell.
R: A cell keeps its chemical composition steady within its boundary. (AIIMS 2002)

64. A: Living organisms are regarded as closed systems.
R: Energy of living organisms cannot be lost or gained from the environment. (AIIMS 2002)

65. A: The number of cells in a multicellular organism is inversely proportional to the size of the body.
R: All the cells in the biological world are of same size. (AIIMS 2002)

66. A: A cell membrane shows fluid behaviour.
R: A membrane is a mosaic or composite of diverse lipids and proteins. (AIIMS 2003)

67. A: *Rhoeo* leaves contain anthocyanin pigments in epidermal cells.
R: Anthocyanins are accessory photosynthetic pigments. (AIIMS 2003)

ANSWERS

1. (a) 2. (a) 3. (a) 4. (b) 5. (a) 6. (a) 7. (c) 8. (d) 9. (c) 10. (c)
11. (a) 12. (a) 13. (a) 14. (a) 15. (b) 16. (d) 17. (b) 18. (a) 19. (c) 20. (c)
21. (d) 22. (a) 23. (b) 24. (a) 25. (c) 26. (a) 27. (c) 28. (c) 29. (a) 30. (a)
31. (a) 32. (c) 33. (a) 34. (c) 35. (c) 36. (d) 37. (b) 38. (a) 39. (a) 40. (a)
41. (a) 42. (b) 43. (c) 44. (d) 45. (c) 46. (a) 47. (b) 48. (a) 49. (a) 50. (d)
51. (d) 52. (b) 53. (c) 54. (c) 55. (a) 56. (a) 57. (d) 58. (a) 59. (a) 60. (b)
61. (a) 62. (d) 63. (a) 64. (d) 65. (d) 66. (a) 67. (c)

UNIT-3

- Molecular Biology
- Genetics
- Test Paper—Unit-3
- Assertion-Reason Type Questions—Unit-3

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0300-8037433

study of Physico-chem... organization of bio-molecules.

7

Molecular Biology

- Nucleic acids
- Evidences in favour of DNA as genetic material
- DNA
- Differences between RNA and DNA
- Types of non-genetic RNA
- Autocatalytic functions of DNA-replication, transcription, translation
- Operon model
- Gene and gene action
- Molecular structure of gene—cistron, muton, recon
- Some specific terms—transposons or jumping genes, retroposons, split genes, pseudogenes, inducible genes, repressible genes and house-keeping or constitutive genes
- Genetic code
- Genetic engineering—restriction enzymes, recombinant DNA technology, PCR, molecular probes, blotting pattern, DNA fingerprinting
- Genomics—Principles and applications

DNA - Replication

- Nucleic acids are highly complex organic acids, present in all living cells.
- Nucleic acid was first isolated (or discovered) by F. Meischer (1869) from pus cells. This was actually DNA, but was given the name Nuclein.
- The name **nucleic acid** was given to this substance because it occurs primarily in **nucleus** and is having **acidic nature.**
- There are two types of nucleic acids:
  1. DNA (Deoxyribonucleic acid)
  2. RNA (Ribonucleic acid).
- DNA occurs mainly in **nucleus**, forming major chemical proportion of chromosomes. Some amount of DNA is also present in **cytoplasm** (mitochondria and plastids).
- RNA is mainly found in **cytoplasm** but some amount of it occurs in ribosomes of nucleus, nucleolus and also in chromosomes or chromatin.
- DNA forms **genetic material** (hereditary material) of most of the organisms **except plant viruses** and some **bacteriophages**, where RNA forms the genetic material. RNA mainly performs **non-genetic functions** related with protein synthesis.

EVIDENCES IN FAVOUR OF DNA AS GENETIC MATERIAL

Chromosomes are the structures responsible for heredity, which are chemically having **proteins** and **nucleic acids**. Until 1949, proteins were considered to be playing an informational role. But **A. Mirsky and H. Ris** (1949) reported that all cells of organism are having constant amount of DNA and different amounts of proteins, which favours DNA as genetic material.

Different evidences in favour of DNA as genetic material are—

1. Transformation experiments or Griffith effect

by

- Strongest evidence in favour of DNA as genetic material comes from Transformation experiment or Griffith effect.
- Griffith (1927) worked on the effect of *Diplococcus pneumoniae* bacteria on mice.
- *Diplococcus pneumoniae*: have

2 strains: Capsulated or S-III type (virulent)

2 strains: Non-capsulated or R-II type (less virulent)

- 4 sets of experiments were performed:

(a) S-III type bacteria $\xrightarrow{\text{injected into}}$ Healthy mice $\longrightarrow$ **mice killed.**

(b) R-II type bacteria $\xrightarrow{\text{injected into}}$ Healthy mice $\longrightarrow$ **mice not killed.**

(c) S-III type bacteria $\xrightarrow{\text{high temp.}}$ Heat killed S-type bacteria $\xrightarrow{\text{injected into}}$ Healthy mice $\longrightarrow$ **mice not killed.**

(d) Heat killed S-III type bacteria + R-II type bacteria $\xrightarrow{\text{injected into}}$ Healthy mice $\longrightarrow$ ***mice killed.**

- When killed mice in set (d) were **post-mortemed** to find cause of death, it was found that these killed mice had **normal S-III type bacteria.**
- Griffith reported that **'SOMETHING'** passed from **heat killed S-type bacteria to R-type bacteria and changed or transformed R-type into S-type.**
- This **SOMETHING** was found to be DNA by Avery, McLeod and McCarty (1944), which transformed bacteria

from non-virulent to virulent. Thus DNA is confirmed to be the genetic material.

2. Evidence from bacteriophage infection

- Hershey and Chase (1952) by his Wareing-blender experiment confirmed that DNA of **bacteriophage** (virus, infecting bacteria) enters into host (bacterial) cell and carries the necessary information for formation of new phages.
- Two types of phage particles, *i.e.*, S^{35} and P^{32} types, were produced by growing in bacteria with radioactive S^{35} and P^{32}. These two types were separately made to infect normal bacterial cells. When these normal bacterial cells were analysed for radioactivity, no S^{35} was reported and only **P^{32} was reported** in bacterial cells, which were infected with P^{32} phage.
- This is because **sulphur** (S) does not form part of DNA and **phosphorus** (P) only forms part of DNA, hence P^{32} radioactivity was found in bacterial cell infected with P^{32} phage, which confirms **DNA to be the genetic material**.

3. Constancy of DNA

Constancy of DNA in all cells of an organism also favours DNA as genetic material.

RNA as genetic material in plant viruses

how RNA

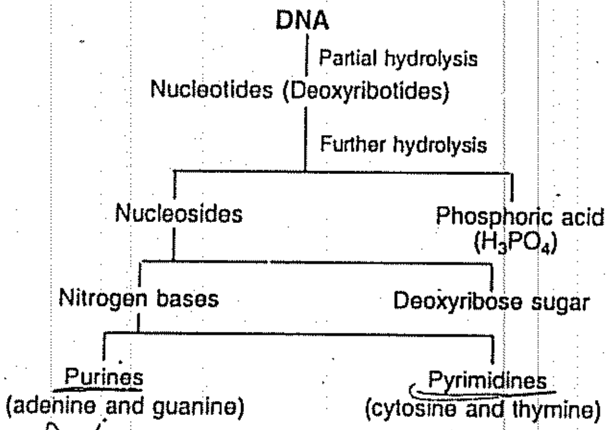
- RNA as genetic material in plant viruses, *e.g.*, TMV (tobacco mosaic virus) was shown by **Fraenkal Conrat**.
- TMV—2 parts ⟨ RNA / Proteins

When RNA was made to infect tobacco plant, it caused **tobacco mosaic disease**, whereas when protein part was made to infect tobacco, no infection was caused. So this confirms RNA as genetic material in TMV.

DNA (DEOXYRIBONUCLEIC ACID)

DNA was first discovered by **F. Meischer** (1869) from pus cells (as nuclein).

- DNA is **long, unbranched, spirally coiled** in eukaryotes and **circular** in prokaryotes as well as in mitochondria and plastids.

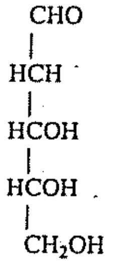


A, G C, T.

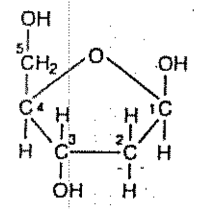
- It is macromolecule of high molecular weight and **nucleotides** are the building blocks or monomeric units (like amino acids in proteins).
- These nucleotides are **not stable**, but can be further hydrolysed to purines and pyrimidine bases, sugar and H_3PO_4.
- So chemically, there are 3 components in DNA:

1. Sugar

Pentose sugar (5C) called **Deoxyribose** (2-Deoxyribose)



2-Deoxyribose



Deoxyribose sugar

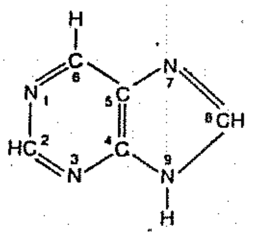
Fig. 7.1. Ring Structure of Deoxyribose sugar

2. Phosphoric acid (H_3PO_4)

3. Nitrogen bases

These are nitrogen containing organic ring compounds and are of 2 types:

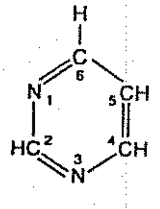
(i) Purines: Two ringed nitrogenous compounds, *e.g.*, Adenine and Guanine. Purines are **9-membered** double rings (*i.e.*, imidazole ring joined to pyrimidine ring at 4′ and 5′ positions). Further a purine has four N-atoms at 1′, 3′, 7′ and 9′ positions.



Purines

Fig. 7.2. General Structure of Purines

(ii) Pyrimidines: Single ringed nitrogenous compounds, *e.g.*, Cytosine and Thymine. Pyrimidines are 6-membered rings. Further a pyrimidine has two N-atoms at 1′ and 3′ positions.



Pyrimidines

Fig. 7.3. General Structure of Pyrimidines

- **Purines** are two:
  - (a) **Adenine or 6-aminopurine**
  - (b) **Guanine or 2-amino, 6-oxy purine**

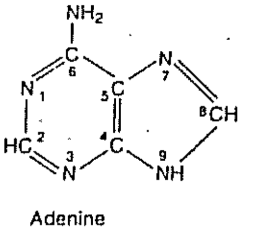


Fig. 7.4. Structure of adenine (purine)

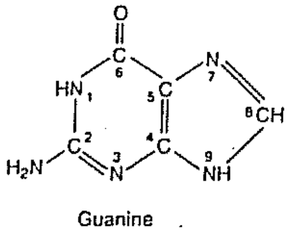


Fig. 7.5. Structure of guanine (purine)

- **Pyrimidines** are also two:
  - (a) **Cytosine or 6-amino, 2-oxy pyrimidine**
  - (b) **Thymine or 2,6-oxy, 5-methyl pyrimidine**

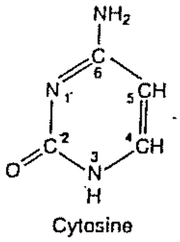


Fig. 7.6. Structure of cytosine

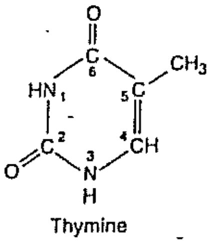


Fig. 7.7. Structure of thymine

always.
A=T &
G=C

S.N.	N-Base	Base + deoxyribose sugar = deoxyribonucleoside	Nucleoside + phosphoric acid = deoxyribonucleotide
1.	Adenine	Deoxyadenosine	Deoxyadenosine monophosphate
2.	Guanine	Deoxyguanosine	Deoxyguanosine monophosphate
3.	Cytosine	Deoxycytidine	Deoxycytidine monophosphate
4.	Thymine	Deoxythymidine	Deoxythymidine monophosphate

- These above four nucleotides (Deoxyribonucleotides) form monomeric units of DNA.

Polynucleotide chain—Adjacent nucleotides are joined together by **'phosphodiester bonds'** to form a **polynucleotide** chain in the manner as shown in Fig. 7.9.

In a nucleotide, N-base is attached to deoxyribose sugar at C-1 and phosphoric acid is attached at C-5 of sugar. Similarly in a polynucleotide chain, adjacent nucleotides are joined together by 'phosphodiester bond' between C-3 and C-5 of different deoxyribose sugars of two adjacent nucleotides.

Further, one end of the polynucleotide chain has a sugar residue with C-3 not linked to another nucleotide and the other end with sugar residue with C-5 not linked. These are named as 3′ and 5′ ends (three and five prime ends) of polynucleotide chain respectively. This chain is not straight but helical in structure (see Fig. 7.9).

Double helix structure of DNA: J.D. Watson and F.H.C. Crick (1953) suggested double helical structure of DNA in the journal '*Nature*' (April issue). According to them, DNA consists of two **antiparallel and complementary** polynucleotide chains joined by H-bonds.

The unique features of pairing between N-bases are:

(i) Purines (A and G) pair with pyrimidines (C and T).

(ii) 'A' pairs with 'T', *i.e.*, A=T and 'G' pairs with 'C', *i.e.*, G≡C.

(iii) The base ratio A + T/C + G may vary in DNA of different groups of organisms but is constant for a particular species.

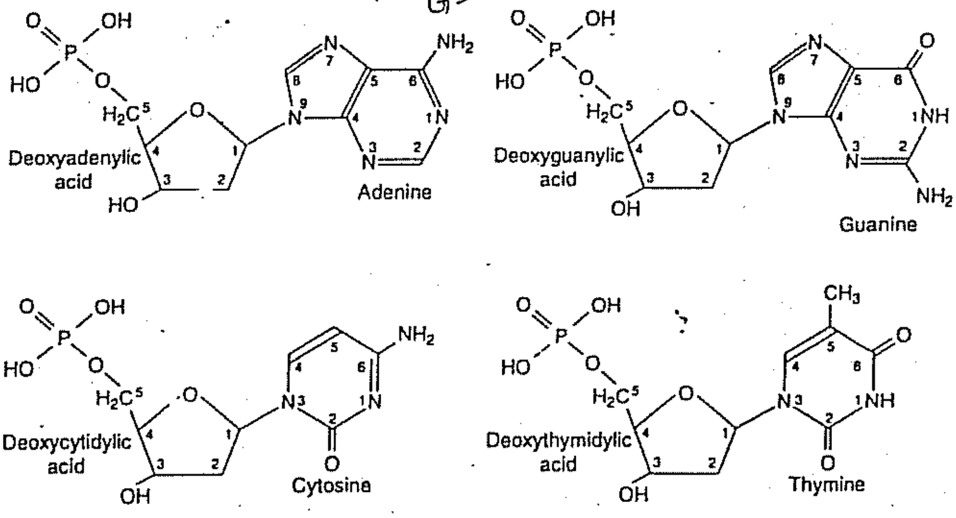


Fig. 7.8. Structure of four different nucleotides

Py Pu
T C A G.

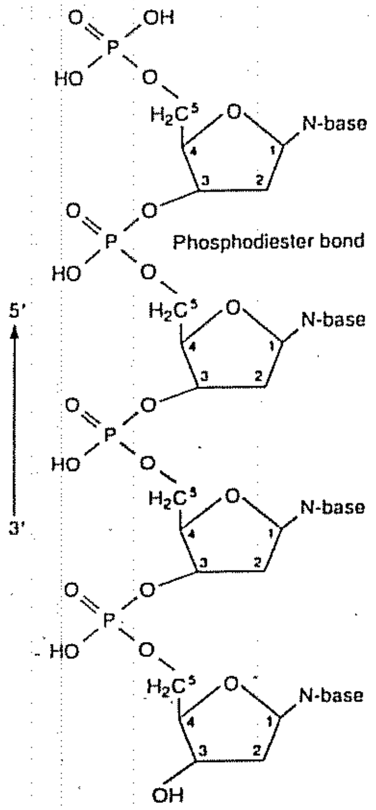

OH
O
P
HO
O
H_2C^5
O
N-base
4
1
3
2
O
Phosphodiester bond
5'
3'
OH

Fig. 7.9. Structure of a polynucleotide chain

- E. Chargaff (1950) discovered the rules of DNA base composition as:

  $[A] = [T] \quad [G] = [C] \qquad [A] + [T] \neq [G] + [C]$

These findings give DNA specificity and individuality from one organism to another.

Later on M.H.F. Wilkins and R. Franklin with the help of X-ray crystallography confirmed double helical structure of DNA, having **diameter of 20 Å and pitch of turn 34 Å. Watson and Crick** along with **Wilkins** and **Franklin** got the **Nobel Prize** for this work in 1962.

Following are the general features of double helix model of DNA:

1. DNA consists of two **complementary** and **antiparallel polynucleotide chains,** coiled about an imaginary axis in such a way that they can be separated only by uncoiling them and lateral separation is not possible.
2. The N-bases are at right angles to long axis.
3. The two antiparallel chains have complementary base sequences, *i.e.,*
   A═T and G≡C (═ double H-bond, ≡ triple H-bond).
4. Distance between base pairs is 3.4 Å and since pitch of one turn is 34 Å, so there are **10 base pairs** in each turn.

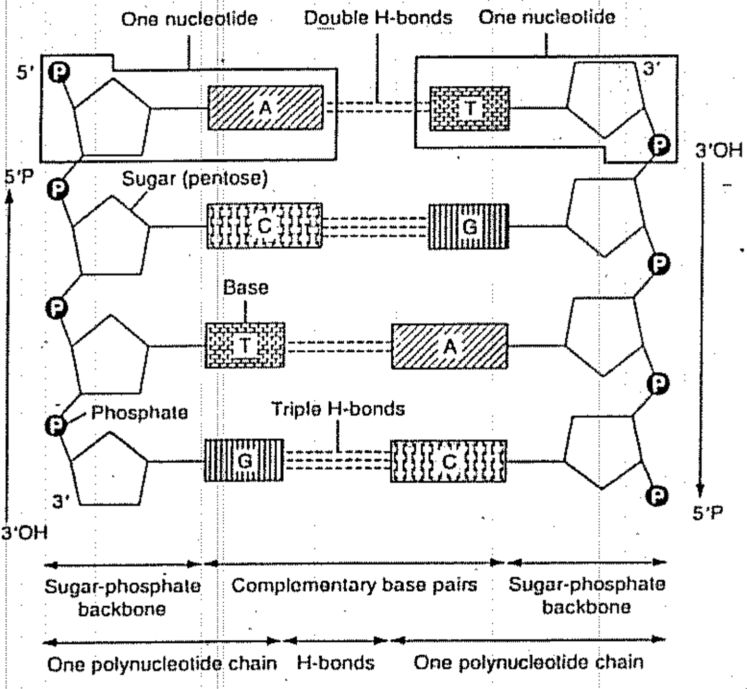

One nucleotide
Double H-bonds
One nucleotide
5'
3'
P
A
T
3'OH
5'P
Sugar (pentose)
C
G
Base
T
A
Phosphate
Triple H-bonds
G
C
3'
3'OH
5'P
Sugar-phosphate backbone
Complementary base pairs
Sugar-phosphate backbone
One polynucleotide chain
H-bonds
One polynucleotide chain

Fig. 7.10. Diagrammatic representation of Watson's and Crick's model of DNA

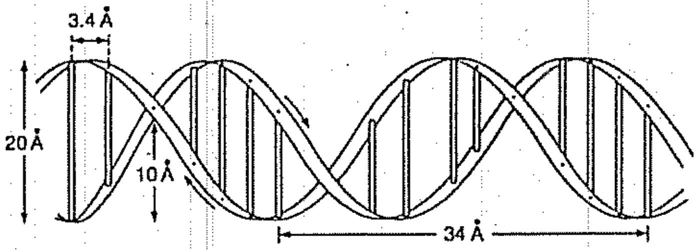

3.4 Å
20 Å
10 Å
34 Å

Fig. 7.11. Watson's and Crick's model of DNA double helix

5. The choice of base pairing is clear because purines are two ringed N-compounds and would need much space, whereas pyrimidines are single ringed which occupy little space and hence purines always pair with pyrimidines to **maintain constant diameter** of 20Å.

- This normal type of DNA is **right handed coiled** and is known as **B-DNA.**

Template or Nonsense or Noncoding or Antisense and Nontemplate or Coding or Sense strands of DNA: Formation of m-RNA from DNA is called transcription. The language in DNA and RNA is the same (*i.e.,* consists of base sequences). In copying DNA into RNA, there is transcription of information and DNA is said to be **transcribed** (RNA molecules produced are called **transcripts**). m-RNA synthesis occurs along one of two strands of

DNA under the influence of RNA-polymerase enzyme, which moves in 3′ to 5′ direction along DNA strand forming m-RNA strand in 5′ → 3′ direction. This DNA strand is copied only in complementary sense (A in the template becomes U in the copy and so on).

The strand of DNA that acts as template for m-RNA synthesis is called **template strand** and the other one is called **nontemplate strand**. m-RNA formed has the information for the sequence of amino acids in a protein, *i.e.*, carries the sense or message of the DNA (gene) to the translational machinery. Further the base sequence of the m-RNA is the same (apart from T → U switch) as that of nontemplate DNA strand and thus nontemplate strand is also called coding or sense strand. The template strand, therefore, is called nonsense or noncoding strand. This template strand or DNA strand that is transcribed is also termed as antisense strand because it is complementary to RNA, which contains the information or has the sense.

- In viruses, the template strand is generally called minus strand (–) and nontemplate strand as plus strand (+).

DNA
5′ CGATGCAT 3′
(Nontemplate or coding or sense strand)
3′ GCTACGTA 5′
(Template or noncoding or nonsense or antisense strand)
5′ CGAUGCAU 3′
(m–RNA strand)

Fig. 7.12. Relationship of transcribed m-RNA to two strands of DNA

Denaturation of DNA: On heating the DNA at 80°C or more, weak H-bonds between two strands break and single stranded flexible DNA is formed, which is known as **denaturation of DNA** (thermal denaturation or DNA melting).

- It has been observed that higher the G-C content (% G + % C) of DNA, the higher the melting temperature, *i.e.*, there is increased stability of G-C containing DNA (as G-C pairs by three hydrogen bonds). Further, even in a single DNA molecule, A-T rich portions melt before G-C rich portions (due to presence of the extra H-bond between G-C as compared with A-T).
- Slow cooling (Annealing), however, again leads to formation of double stranded DNA, called **renaturation** of DNA.

Significance of DNA: Three primary functions have been assigned to DNA:

(i) **Storage of genetic information:** DNA is the molecular 'blue print' (stored record) of instructions which determine all heritable characteristics of an organism.

(ii) **Self-duplication (replication) and inheritance:** DNA contains the information for its own duplication or replication, which provides the means or method of transmission of genetic instruction from one cell to its daughter cells or from one organism to its progeny or offsprings.

(iii) **Expression of genetic message:** Information stored in DNA is put to use to direct the synthesis of specific proteins or polypeptides.

Some special forms of DNA

Besides normal or right handed DNA (B-DNA), some other forms of DNA are:

1. **Left handed DNA or Z-DNA (Zig-Zag DNA):** In 1979, another form of DNA has been obtained artificially called Z-DNA and main characteristics of this DNA are:

DIFFERENCES BETWEEN RNA AND DNA

There are three types of differences between RNA and DNA

	RNA	DNA
(A)	**Locational difference:**	
	RNA is mainly found in cytoplasm. Some amount is also present in nucleolus and nucleoplasm.	DNA mainly occurs in nucleus. Some amount of it is also present in mitochondria and plastids (cytoplasm).
(B)	**Structural differences:**	
	(i) Sugar present in RNA is ribose sugar (5C).	(i) Sugar present in DNA is deoxyribose sugar (5C).
	(ii) Nitrogen bases are adenine, guanine (purines), cytosine and uracil (pyrimidines), *i.e.*, thymine (T) in DNA is replaced by uracil (U) in RNA.(Uracil: 2,6-oxypyrimidine).	(ii) N-bases are: Adenine, guanine (purines) and cytosine, thymine (pyrimidines).
	(iii) RNA consists of generally single polynucleotide chain, but in some cases, double stranded RNA is also present, *e.g.*, Wound tumour virus, reoviruses.	(iii) DNA is mostly double stranded, but rarely single stranded DNA is also found, *e.g.*, in ϕ × 174 bacteriophage.
(C)	**Functional difference:**	
	RNA generally performs non-genetic functions related with protein syntehsis. However, rarely it performs genetic function, *e.g.*, in plant viruses and some bacteriophages like MS 2, F 2, r 17, etc.	DNA is mostly genetic material, *i.e.*, performs genetic function.

(i) Left handed coiled.
(ii) Due to different arrangement of molecules, the phosphate backbone follows a zig-zag course.
(iii) In Z-DNA, sugar molecules have alternating orientation, so **repeating unit is dinucleotide** (as against mononucleotide in B-DNA).
(iv) Pitch of turn = 45 Å (as against 34 Å in normal DNA).
(v) Diameter of Z-DNA is about 18 Å (as against 20 Å in B-DNA).
(vi) One turn is having **12 base pairs** (6 dinucleotide units), while in B-DNA 10 base pairs are there.

o **Alexander Rich** discovered this new DNA structure and named it as Z-DNA.
The Z-DNA may play a role in regulation of gene activity and/or in genetic recombination.

2. **Promiscuous DNA:** Special type of DNA which makes movement between mitochondria, chloroplast and nucleus, is called **Promiscuous DNA.**

It was discovered in 1983 in Cambridge university in maize. It was later reported in **yeast, mungbean, spinach and peas.**

3. **Repetitive DNA:** Multiple copies of DNA having same or almost same base pair sequence constitute **Repetitive DNA.** In higher organisms, 20%–90% DNA is of this type.

4. **Satellite DNA:** In some eucaryotes, small highly repetitive DNA sequences have been found called **Satellite DNA,** which differ in average base composition.

TYPES OF NON-GENETIC RNA

Generally RNA performs the non-genetic functions, related with **synthesis of proteins,** by means of following 3 types of RNA's:

1. Messenger RNA (m-RNA)

- m-RNA is formed as a **complementary strand** on one of the two strands of DNA **inside nucleus.** Soon after its formation, m-RNA comes out in cytoplasm.
- Formation of m-RNA from DNA is called **transcription.**
- The name m-RNA (messenger RNA) was given by **Jacob and Monod** (1961), because it is responsible for carrying the genetic information present in DNA, *i.e.*, acts as messenger of informations contained in DNA.
- m-RNA forms only **5–10%** of total RNA present in the cell.
- Molecular weight of m-RNA is **5,00,000 to 10,00,000.**
- It is **short-lived RNA,** *i.e.*, RNA with minimum age and dies **after few translations.**
- Function of m-RNA is to carry the genetic information present in DNA (inside nucleus) to cytoplasm for protein synthesis.

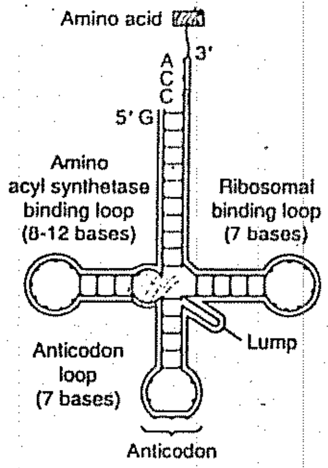
2. Ribosomal RNA (r-RNA)

- r-RNA is formed in **nucleolus** and it forms **80%** of total RNA present inside the cell, *i.e.*, **most abundant type of RNA** present in cell.
- r-RNA is the **most stable** type of RNA.
- Its mol. wt. is **40,000 to 10,00,000.**
- r-RNA is associated with structural organization of ribosomes (r-RNA forms about 60% of weight of ribosomes), which are seats of protein synthesis.

3. Transfer RNA (t-RNA)

- t-RNA is also called **soluble RNA** (s-RNA) or **adoptor-RNA** or **adoptive-RNA.**
- t-RNA forms 10–15% of total RNA present in the cell.
- These are smallest molecules of RNA, having only 75-95 bases in their polyribonucleotide chains.
- Mol. wt. of t-RNA molecule is **25,000-40,000.**
- This is most studied type of RNA and is found to contain many **unusual modified bases like inosine, pseudouridine and dihydrouridine.**
- t-RNA acts as adoptor molecule which carries **amino acids** to the site of protein synthesis (*i.e.*, ribosomes).
- Most accepted model for **t-RNA structure** is **'clover leaf model',** which was given by **Robert Holley** (1965) along with **H.G. Khorana** and Nirenberg (for yeast alanyl t-RNA) and for this work, they were awarded Nobel Prize in 1968. According to this model, yeast **alanyl t-RNA** molecule is having single polynucleotide chain of 77 nitrogen bases folded in such a way that it appears to be double stranded. This chain is having unpaired base sequence **CCA at 3′ end** and G (guanine) at 5′ end.
- **Amino acids are attached to 3′ end.**

DNA
↓
m-RNA
↓


Amino acid
3'
A
C
C
5' G
Amino acyl synthetase binding loop (8-12 bases)
Ribosomal binding loop (7 bases)
Lump
Anticodon loop (7 bases)
Anticodon

zig zag course

Adoptck.

adoptor

Fig. 7.13. Clover leaf model of t-RNA structure

Heterogenous RNA or H_n-RNA or d-RNA (DNA like RNA)

This type of RNA is present in nucleus, which is having larger molecules and act as **precursors of m-RNA.**

Some Important points to remember

- **C-Value**—Haploid DNA content of an organism is known as **C-Value.**
- Nobel Prize for artificial synthesis of DNA (gene) or DNA synthesis *in vitro* was given to **A. Kornberg** (1959).

- Nobel prize for artificial synthesis of RNA was given to S. Ochoa (1959).

AUTOCATALYTIC FUNCTIONS OF DNA

Through its three **autocatalytic functions**, DNA helps the organism to show symptoms of life related with growth and reproduction and hence it is considered to be very important material.

3 autocatalytic functions of DNA are—

1. **Replication**
2. **Transcription**
3. **Translation**

Replication Transcription Translation

1. Replication

- Formation of new DNA from old DNA is called replication of DNA or it is DNA duplication.
- Replication of DNA is **semiconservative**, *i.e.*, from one DNA molecule, two new DNA molecules are produced and in each new DNA molecule, one strand is of parental type and another is formed as new. So parental identity is **conserved upto half extent** and hence DNA replication is **semiconservative**.

Further, DNA replication is semidiscontinuous. During replication, 2 strands of DNA separate or double stranded DNA uncoils by action of enzymes **topoisomerases, helicase or unwindase** enzyme **(unwinding protein)** and **single-strand binding protein (SSB). Topoisomerases (like DNA gyrase)** found in both **prokaryotic and eukaryotic cells are able to change the supercoiled state of DNA duplex. Helicase moves along the DNA and catalyzes the ATP-driven unwinding of the duplex and as DNA is unwound, the strands are prevented from reforming the duplex by SSB proteins.**

Now under the influence of enzyme **DNA polymerase III** (discovered by **A. Kornberg**), new DNA strand is formed on 3′ to 5′ strand continuously in 5′ → 3′ direction. This strand which is formed **continuously** is called leading strand. On the other strand (*i.e.*, 5′ to 3′ strand), using the same enzyme, new strand is formed discontinuously or in the form of small segments or pieces (This strand is again formed in 5′ → 3′ direction). This strand which is formed **discontinuously** or in form of small segments is called **lagging strand**.

- **The small segments** of DNA on lagging strand are called **Okazaki pieces** after the name of their **discoverer**. These **Okazaki pieces** are later on joined together with the help of **DNA-ligase enzyme or polynucleotide ligase enzyme** (discovered by **H.G. Khorana**) to form complete strand. Due to the fact that DNA replication occurs continuously on one strand and discontinuously on other strand, the replication of DNA is said to be **semidiscontinuous**.

The enzymes responsible for DNA replication are—

(i) DNA polymerase III or polynucleotide polymerase (discovered by **A. Kornberg**).

(ii) DNA ligase or polynucleotide ligase (discovered by H.G. Khorana).

- In prokaryotes, three different DNA polymerases are known—DNA polymerase I, II and III. DNA polymerases I and II are responsible for DNA repair whereas DNA polymerase III is meant for actual DNA replication. DNA polymerase I has 5′ → 3′ polymerising activity (due to which it removes or excises RNA primers from Okazaki pieces and fills it with DNA) as well as 3′ → 5′ and 5′ → 3′ exonuclease activity (due to which mispaired nucleotide is removed. This is called **proof reading function**). DNA polymerase II has 5′ → 3′ polymerising activity as well as 3′→5′ exonuclease activity but lacks 5′ →3′ exonuclease activity. Further both of these enzymes have single polypeptide chain. DNA polymerase III has heteromultimeric chain and has essential role in DNA replication. This enzyme has 10 units and all of these sub-units are needed for DNA replication *in vitro*. This enzyme also has both 5′ → 3′ polymerising activity as well as 3′→5′ exonuclease activity (proof reading activity). Number of nucleotide molecules polymerised per minute at 37°C by DNA polymerase III enzyme is upto 15,000 (as against upto 1000 and 50 in DNA polymerase I and DNA polymerase II respectively).

In eukaryotes, five different DNA-polymerases have been identified—DNA polymerases α, β, γ, δ and ε.

Evidences in favour of semiconservative mode of DNA-replication

1. **Evidence from Meselson and Stahl's experiment** (1958) in *E. coli* using heavy nitrogen (N^{15}). In this experiment, N^{15} was used in the culture medium for many cell generations, which replaced all N^{14} in DNA by N^{15}. These cells having N^{15} in DNA were now transferred to N^{14} (normal nitrogen) medium. DNA was then analysed after known number of replications. After one generation, DNA molecules were having heavy nitrogen (N^{15}) in one strand and normal nitrogen (N^{14}) in another strand. Similar was the case found in further generations of replications.

2. **Evidence from Taylor's experiment** on *Vicia faba* root tips using **autoradiography technique** and further he used **tritiated** thymidine (H^3-tdR).

   ○ Taylor's experiment demonstrates the semiconservative mode of replication in the chromosomes of higher plants.

3. **Evidence from Cairn's autoradiography experiment** in bacteria. He also used H^3-tdR (tritiated thymidine).

   ○ It was observed that if **tritiated thymidine** (H^3-tdR) is present in both DNA strands initially, the number of molecules of DNA having H^3-tdR after three replications is found to be only two (in eight) which supports **semiconservative mode** of replication.

2. Transcription

Simply, formation of m-RNA from DNA is called transcription.

Or

Transfer of genetic information from DNA to m-RNA is called transcription.

- Transcription occurs with the help of enzyme **RNA-polymerase**. In **prokaryotic** cells, single type of RNA polymerase is present. RNA polymerase (RNAP) in *E. coli* consists of **five polypeptide chains**, *i.e.*, two chains of **alpha** (α) polypeptide and one chain each of **beta** (β), **beta dash** (β′) and **sigma** (σ) polypeptides. Thus RNAP can be represented as $\alpha_2\beta\beta'\sigma$, in which $\alpha_2\beta\beta'$ form **core enzyme** and σ factor is not firmly attached to it. β and β′ polypeptides form **catalytic centre** of RNAP, which helps the enzyme in unwinding of DNA molecule for transcription. The σ factor helps in selecting the initiation sites on DNA molecule and two α polypeptides are responsible for promotor binding.

In **eukaryotic** cells, **three** distinct types of RNA polymerases are present—**RNA polymerase I** is responsible for synthesis of large (28 S, 18 S and 5·8 S) ribosomal RNAs (r-RNAs); **RNA polymerase II** synthesizes messenger RNAs (m-RNAs) and most small nuclear RNAs; and **RNA polymerase III** synthesizes various transfer RNAs (t-RNAs) and 5S r-RNA.

- Transcription is the first step of protein synthesis.
- $\text{DNA} \xrightarrow{\text{transcription}} \text{m-RNA} \xrightarrow{\text{translation}} \text{Protein}$

This **one-way flow** of information from DNA to m-RNA and then to protein is called the **central dogma** of molecular biology by **F.H.C. Crick** (1958).

But later on two American workers **H. Temin** and **D. Baltimore** reported that there also occurs formation of DNA on RNA template or DNA is also formed from RNA in **RNA-tumour virus** (Rous-sarcoma virus). This is called **reverse transcription** or **Teminism**, *i.e.*,

$$\text{DNA} \underset{\text{Reverse transcription}}{\overset{\text{transcription}}{\rightleftarrows}} \text{m-RNA} \xrightarrow{\text{translation}} \text{Protein}$$

- This reverse transcription occurs under the influence of **reverse transcriptase** enzyme.

This discovery of reverse transcription proved to be very useful in cancer studies.

For this work, **Temin, Baltimore** and **Dulbecco** were given **Nobel Prize** (1975).

3. Translation

This is the second step of protein synthesis.

- The translation of language of DNA, which is now present in m-RNA into language of proteins is called **translation.**

  Or

  Simply **formation of protein** with the help of information present in m-RNA is called **translation.**
- Translation is a complex process and is completed in different steps like—
  (a) Activation of amino acid with the help of **ATP** and **amino acyl synthetase** enzyme.
  (b) Attachment of activated amino acid to t-RNA molecule (at 3′ end).
  (c) Initiation of polypeptide by methionine amino acid (coded by AUG, rarely by GUG). In prokaryotes, initiating codon always functions in combination with **SD region** of m-RNA (Shine-Delgarno sequence). After 30 S–50 S association, f-met-$\text{tRNA}_f\,met$ (formylated methionine attached to $\text{t-RNA}_f\,met$) gets located on ribosomal **P site** (peptidyl site), so that it can form a peptide bond with the incoming aminoacyl t-RNA encoded by second m-RNA codon on ribosomal **A site** (aminoacyl site).
  (d) Elongation of polypeptide by regular addition of different amino acids. This process is completed in following 3 steps:
    (i) Binding of AA-tRNA (aminoacyl tRNA) at **site A** of ribosome. It is now considered that AA-tRNA first binds to **R site** (present on smaller or 30 S subunit of ribosome. Later on it is flipped to A site using energy from GTP (guanosine triphosphate).
    (ii) Formation of peptide bond between free-COOH group of peptidyl tRNA at P site and free-NH_2 group of aminoacyl t-RNA at A site with the help of **peptidyl transferase** enzyme.
    (iii) Translocation of peptidyl tRNA from site A to site P. As deacylated tRNA is liberated from site P, the peptidyl tRNA is translocated from A to P site with the help of one GTP molecule (*i.e.*, require energy).
- This process of elongation of polypeptide chain (protein mol.) continues unless there is **nonsense codon** or **chain termination codon** on m-RNA. There are 3 nonsense codons, *viz.* UAA, UAG and UGA.

  (First amino acid is always **methionine**). In prokaryotes, initiating amino acid (methionine) is **formylated** and hence there are two tRNAs for methionine, *i.e.*, $\text{tRNA}_f\,met$ (formylatable) and $\text{tRNA}_m\,met$ (non-formylatable). But in eukaryotes, initiating amino acid (methionine) is not formylated due to absence of $\text{tRNA}_f\,met$ in plants and due to absence of enzyme **transformylase** in animals.
- This polypeptide chain formation (protein mol.) is fast process and in bacteria, protein of 300 amino acids is formed in 20 seconds.

OPERON MODEL

Operon model was given by Jacob and Monod (1961) for regulation of protein synthesis in prokaryotes. In bacteria, the genes that contain the information for assembling the enzymes of a metabolic pathway are usually clustered together on the chromosome in a functional complex called an **operon.**

- **Operon** is a set of **structural genes** (cistrons) and associated control genes, *i.e.*,

$$\text{Operon} = \underset{\text{(Cistrons)}}{\text{Structural genes}} + \underset{(i)}{\text{regulator gene}} + \underset{(p)}{\text{promotor gene}} + \underset{(o)}{\text{operator gene}}$$

- **Regulator** gene (i) controls the activity of **operator** gene (o) by producing **repressor molecules** or it codes for repressor protein (gene regulatory protein).
- **Promotor** gene (p) is the actual site of start of transcription and it is the site where RNA polymerase binds to the DNA prior to beginning of transcription. It lies to the left of operator gene. **Operator gene** (o) controls the activity of

Molecule

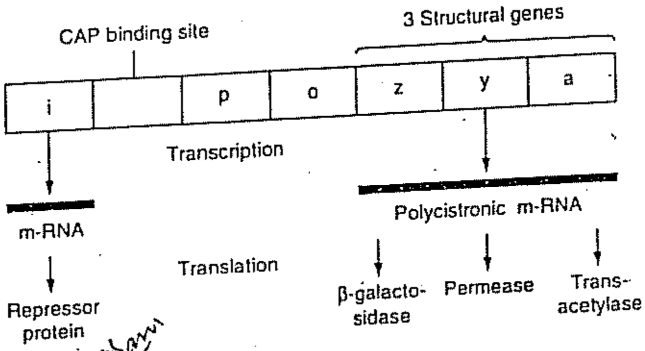
[illegible] binding repressor

(CAP binding [illegible])

2) tryptophan [illegible]

structural genes taking part in the synthesis of proteins. Operator is situated between the promotor and first structural gene where it serves as binding site for repressor protein.

The interplay among these various elements is illustrated by lac operon (cluster of genes that regulates production of enzymes needed to metabolize lactose in bacterial cells (*E. coli*). It is an **inducible operon** (in which presence of key metabolic substance, *i.e.*, lactose induces transcription of the structural genes or active repressor + inducer = inactive repressor). The lac operon can be represented by the following simple diagram:



diagram

Fig. 7.14. Diagram of lac operon

- In lac operon of *E. coli*, activity of **regulator gene** (i) synthesizes **repressor molecules**, which get attached to operator gene and thus **checking m-RNA synthesis** (*i.e.*, **transcription is checked**) and hence no protein synthesis occurs.

If lactose (inducer) molecules are added, they get attached with **repressor molecules** which become inactive and they cannot attach on operator gene (o), due to which m-RNA is synthesized from structural genes (*i.e.*, transcription occurs) and hence proteins are synthesized. The system of regulation in lac operon is a **negative control** as interaction of DNA with repressor protein inhibits gene expression or operon is normally 'on' but is kept 'off' by regulator gene. However, lac operon is also under positive **control through catabolite gene uctivator protein (cga protein)** or **Cyclic AMP receptor protein (CAP)**. The lac promotor on its own is a weak one so RNA polymerase does not readily bind to it and initiate transcription. Without extra help the lac operon is not transcribed except at a low basal level. The extra help in polymerase binding is given by the attachment of the cga protein or CAP, to the adjacent site (CAP binding site). When CAP is attached, the promotor becomes strong one. However, CAP does not attach unless cyclic AMP (cAMP) in bound to it. cAMP is produced by the cell only when glucose levels are low. When glucose level is high, cAMP is rare and CAP does not bind and hence RNA polymerase does not bind effectively and lac operon transcription is minimal (glucose effect).

- When mutation occurs in regulator gene (i), repressor molecules are not produced and hence transcription occurs (m-RNA formation) continuously and hence proteins are synthesized continuously irrespective of need. Such strains where protein synthesis (or enzyme synthesis) occurs continuously are called constitutive strains.

2) [illegible]

- **The tryptophan operon** (trp operon) in bacteria is a repressible operon. Here repressor is inactive and it becomes active as DNA binding protein only when complexed with a **Co-repressor** (tryptophan). In absence of tryptophan, the operator site is open to binding by RNA polymerase, which transcribes the structural genes of trp operon, leading to production of enzymes that synthesize tryptophan. When tryptophan becomes available, the enzymes of tryptophan synthetic pathway are no longer needed and tryptophan (co-repressor)-repressor complex blocks transcription. The regulation of this operon is also a **negative control**.
  - ○ (**Gene Battery Model**—Regulation of protein synthesis in eukaryotes is explained by **Gene battery model** given by **Britten and Davidson**)

Gene Davidson Gene battery

GENE

Term 'gene' was given by **Johannsen** (1909) for any particle to which properties of **Mendelian factor** or **determiner** can be given.

T.H. Morgan (1925) defined gene as—

'Any particle on the chromosome which can be separated from other particles by mutation or recombination, is called a gene.'

In general, **gene is the basic unit of inheritance.**

Gene action—Genes act by producing enzymes, *i.e.*, each gene in an organism produces a specific enzyme, which controls a specific metabolic activity.

- **'One gene one enzyme'** theory was given by **Beadle** and **Tatum** (1958), while they were working on red mould or *Neurospora* (Ascomycetes fungus), which is also called ***Drosophila* of plant kingdom.**

  Wild type *Neurospora* grows in a **minimal medium** (containing sucrose, some mineral salts and biotin). The asexual spores, *i.e.*, **conidia** were irradiated with **X-rays** or **UV-rays** (mutagenic agent) and these were crossed with wild type. After crossing sexual **fruiting body** is produced having asci and **ascospores**. The ascospores produced are of 2 types:

  (a) The ascospores, which are **able to grow on minimal medium** (like wild type), called **'prototrophs'.**

  (b) Which do not grow on minimal medium, but grow on **supplemented medium** (containing thiamine), called **'auxotrophs.'**

  Beadle and Tatum explained that thiamine synthesis is completed in different steps and each step is associated with a specific enzyme, which in turn is associated with a specific gene.

In **auxotrophs** (mutated forms), due to mutation in some gene: (by X-rays or UV-rays) synthesis of some enzymes is inhibited and hence synthesis of thiamine is stopped. Thus auxotrophs are unabl to grow on minimal medium.

- One gene one enzyme theory is able to explain som metabolic disorders or inborne errors in human beings like—

  (i) **Phenylketonuria:** This disease is associated with lov mental ability, which is due to accumulation of pheny pyruvic acid in blood. This is due to absence of reverse transcription

particular enzyme, capable of further conversion of phenyl pyruvic acid, which is due to absence or mutation of a specific gene.)

(ii) **Alcaptonuria:** The person suffering from this disease produces urine, which turns black when exposed to air. This is due to accumulation of homogenitisic acid or alcaptan. This accumulation of alcaptan is due to absence of enzyme homogenitisic oxidase which converts alcaptan further. This absence of enzyme is due to mutation of a specific gene.

MOLECULAR STRUCTURE OF GENE

Gene is chemically DNA, but the length of DNA which constitutes a gene, is controversial.

3 terms, *i.e.*, **cistron, muton** and **recon** were given by **Seymour Benzer** to explain the relation between DNA length and gene.

(a) Cistron or Functional gene or Gene in real sense

Cistron is that particular length of DNA which is capable of producing a protein molecule or polypeptide chain or enzyme mol.

- A gene or cistron of a protein will be having N-bases or nucleotides **three times** the number of amino acids in a protein molecule, *e.g.*, A cistron of a protein molecule having 100 amino acids will be having 300 N-bases or nucleotides. (as genetic code is triplet).

(b) Muton or Unit of mutation

Muton is that length of DNA which is capable of undergoing mutation. Muton is having one or part of nucleotide.

(c) Recon

Recon is that length of DNA, which is capable of undergoing crossing over or capable of recombination. Recon is having **one or two pairs of nucleotides.**

SOME SPECIFIC TERMS

1. Transposons or Jumping genes

The term **'transposon'** was first given by **Hedges and Jacob (1974)** for those **DNA segments** which can join with other DNA segments completely unrelated and thus causing **illegitimate pairing.** These DNA segments are transposable and may be present on different places on main DNA. The transposons are thus also called **jumping genes.** Hedges and Jacob reported them in **bacteria.**

- But actual discovery of these was made by **Barbara Mc Clintock (1940) in maize** and she named them as **controlling elements in maize or mobile genetic elements in maize.** For this work, she was awarded **Nobel Prize** in **1983.**
- Transposons are thus variously named as **transposable elements or controlling elements or mobile genetic elements or jumping genes** and are reported in *Drosophila, Antirrhinum* (Snapdragons), *Zea mays,* bacteria, etc.

2. Retroposons

The term was given by **Rogers (1983)** for **DNA segments** which are formed from RNA (RNA origin) or which are formed by **reverse transcription** under the influence of **reverse transcriptase enzyme** or **RNA dependent DNA polymerase enzyme,** *i.e.,*

$$\text{RNA} \xrightarrow{\text{Reverse transcription}} \text{DNA (Retroposon)}$$

- About 10% DNA of genome in **primates** and **rodents** is of this type, *i.e.,* **retroposons.**

3. Split genes or Interrupted genes

Certain genes were reported first in **mammalian viruses** and then in eukaryotes by **R. Roberts and P. Sharp in 1977** which **break up into pieces** or which are made of segments called **exons and introns.** These are called **split genes** or **interrupted genes.**

Split gene = Exons + Introns

- In m-RNA formed from split gene, base sequences corresponding to **only exons** are present and not corresponding to introns. So in split genes, exons carry genetic information or **informational pieces of split genes are exons.**
- **Roberts and Sharp got Nobel Prize (1993)** in medicine and physiology for their work on split genes and RNA processing.

4. Pseudo genes or False genes

DNA sequences present in multicellular organisms, which are useless (apparently) to the organism and are considered to be defective copies of functional genes (cistrons), are called pseudogenes or false genes.

- These have been reported in *Drosophila,* mouse and human beings.

5. Inducible genes, Repressible genes and House-keeping genes or Constitutive genes

Gene expression is mostly regulated on the basis of environment. The expression of a gene in response to a substance in the environment is called **Induction** and the genes which are capable of environmental stimulation are called **Inducible** genes. On the other hand, the genes which are turned off due to presence of a particular substance in the cellular environment, are called **repressible genes.** Still there are other genes **which are always expressed,** are called **constitutive genes or house-keeping genes** and their common functions are required in all types of cells, *e.g.,* RNA-polymerase-determining genes such as t-RNA and r-RNA. The function of these house-keeping genes is called constitutive activity or house-keeping activity.

GENETIC CODE

- Genetic code was discovered by **Nirenberg and Matthaei** (1961).
- Genetic code may be defined as, "Sequence of N-bases or nucleotides in **polynucleotide chain** (DNA molecule), which determines sequence of amino acids in a **polypeptide chain** (protein molecule).

  Or

  'Nitrogen base sequence in DNA or m-RNA which is having information for protein synthesis, is called genetic code'.
- First m-RNA codon discovered by Nirenberg and Matthaei is **UUU,** which codes for **phenyl alanine.**

Restriction endonu and ligase

AUG GUG

Characteristics of genetic code

1. **G. Code is triplet** (*i.e.*, 3-letter codon):
   - Triplet nature of genetic code was proposed by F.H.C. Crick.
     According to him, sequence of 3 N-bases specifies or determines an amino acid, *e.g.*, AUG—codes for methionine amino acid.
   - Number of possible triplet codons is 64.✓

2. **G. Code is degenerate** (*i.e.*, multiple coding system):

As the number of codons is 64 and number of amino acids to be coded is 21, so more than one codons are available for a single amino acid. This multiple coding system is called degenerate code.

3. **G. Code is commaless** (*i.e.*, there is no gap or punctuation):

First three N-bases code one amino acid and next three bases code another amino acid and so on.

4. **G. Code is non-overlapping.**

5. **G. Code is non-ambiguous and universal:**

There is no ambiguity regarding genetic code, *i.e.*, one codon will code for same specific amino acid in all organisms (including bacteria, plants, animals). Thus code is universal.

- Exception is in yeast mitochondria, where UGA codes for **tryptophan** amino acid, however, in other cases, it is nonsense codon.

Chain initiation codon

Chain initiation codon is generally AUG (which always codes for **methionine**) or rarely GUG (GUG when present in beginning codes for **methionine**, but when present in intermediate position, codes for valine).

Chain termination codons (nonsense codons)

There are 3 nonsense codons, *i.e.*, UAA (ochre), UAG (amber) and UGA (opal), which when present in m-RNA, cause **termination** of polypeptide chain (as they do not code for any of the protein amino acids).

Hence these nonsense codons are also called **Chain termination codons.**

Cryptoanalysis of genetic code or Delineation of genetic code

Genetic code was deciphered or broken by **Nirenberg, Robert Holley and H.G. Khorana (1968).**

Wobble hypothesis

This hypothesis was given by **F.H.C. Crick (1965).** According to this **third** N-base of a codon is not much significant and codon is specified by first two bases. Same tRNA can recognize more than one codons differing only at third position.

GENETIC ENGINEERING

This is a recent branch of biology which deals with the synthesis of artificial genes, repair of genes, combining the genes from two organisms and manipulation of genes for improvement of living beings.

In other words, genetic engineering is concerned with laboratory alteration of genes.

- Paul Berg is known as 'Father of Genetic Engineering'.

Restriction endonucleases and **ligase** are the main tools of genetic engineering. During the 1970s, it was found that bacteria contained nucleases that recognize short nucleotide sequences within duplex DNA and cut DNA at highly specific sites on both strands of duplex. These enzymes are called **restriction endonucleases or simply restriction enzymes.** They were given this name because these are used by bacteria to destroy various viral DNAs that enter the cell, thus restricting the potential growth of the viruses.

- Restriction endonuclease enzyme cuts the internal phosphodiester bonds of DNA (while exonuclease enzyme cuts the terminal phosphodiester bonds of DNA). Restriction endonuclease enzymes have two restrictions:
  (i) They act only on ds-DNA (double stranded DNA).
  (ii) They cut the DNA at specific sites.

Different bacteria have different restriction enzymes that recognize different base sequences in the DNA and therefore have different cutting sites. A large number of restriction enzymes cutting at specific base sequences are now known. The sequences recognized by these enzymes are **4 to 8 nucleotides long** and are characterized by a particular type of internal symmetry.

- Restriction enzymes make it possible to cut DNA at precise base sequences with surgical neatness, producing defined fragments, hence these restriction endonucleases are also called 'Biological scalpels' or 'Chemical scissors' or 'Chemical knives'.
- **Arber (Swiss), Nathan and Smith (USA)** got Nobel Prize (medicine and physiology) in 1978 for discovery and use of restriction enzymes in genetic engineering.

Some important examples of restriction enzymes or restriction endonucleases are:

(i) **EcoRI:** It was the first to be isolated from *E. coli* strain R. It recognizes the sequence

$$\begin{array}{c} \downarrow \\ 5'\,\text{GAATTC}\,3' \\ 3'\,\text{CTTAAG}\,5' \\ \uparrow \end{array}$$

UAA UGA
UAG

EcoRI

i.e., it cleaves the DNA between G and A at both ends.

Hae III

(ii) **Hae III:** It is isolated from *Haemophilus aegyptius.* It recognizes the sequence

$$\begin{array}{c} \downarrow \\ 5'\,\text{GGCC}\,3' \\ 3'\,\text{CCGG}\,5' \\ \uparrow \end{array}$$

i.e., cleaves the DNA between G and C.

(iii) **Bam HI:** It is isolated from *Bacillus amyloliquefaciens.* It recognizes the sequence

$$\begin{array}{c} \downarrow \\ 5'\,\text{GGATCC}\,3' \\ 3'\,\text{CCTAGG}\,5' \\ \uparrow \end{array}$$

i.e., cleaves the DNA between G and G at both ends.

From above examples, it is clear that name of restriction enzyme indicates its origin (*e.g.*, EcoRI from *E. coli* and Bam HI from *Bacillus amyloliquefaciens*). Roman numerals are added to distinguish several enzymes with same origin. The sequences recognized by these restriction enzymes have a **two-fold symmetry**, *i.e.*, the partner strand read in 5′ → 3′ direction is identical in sequence. A sequence with this type of symmetry is called palindrome. When restriction enzyme attacks this palindrome, it breaks each strand at the same site in sequence (indicated by the arrows).

- Some of these restriction enzymes cleave bonds directly opposite one another on the two strands producing **blunt ends** (*e.g.*, Hae III), whereas others make **staggered cuts** (*e.g.*, EcoRI, Bam HI).

A large number of restriction enzymes occur in bacteria where they are used in breaking phage DNA without affecting bacterial genome, *i.e.*, they make a bacterial cell immune to bacteriophage.

- Restriction enzymes do not degrade bacterial DNA. The bacterial cell guards against cutting its own DNA by adding a **methyl group** to one of the bases in all of the recognition sequences on each new strand as soon as it is synthesized. The restriction enzyme **no longer recognizes** the methylated sequence and thus the cell's own DNA is immune from attack by that enzyme.

Recombinant DNA technology

Now it has become possible to recombine a segment of DNA from one organism with that of another organism in a test-tube. The hybrid DNA so produced is called **recombinant DNA** or **Chimeric DNA** and the technique of its production is called recombinant DNA technology.

- Paul Berg (1973) first of all synthesized recombinant DNA molecules by using DNA of virus SB-40 and *E. coli*, marking the birth of modern genetic engineering.
- The principle of synthesis of recombinant DNA molecules lies in 'Sticky ends' of DNA pieces. Many restriction enzymes make staggered cut in DNA strands (*e.g.*, EcoRI). The staggered cut produces cohesive or sticky ends. If two pieces of DNA, both having identical sticky ends, they will join together to form recombinant DNA (ligase enzyme is used to seal the nicks in the chain).

Gene library/Genomic library (by shotgun exp.)

In this experiment, genomic DNA is extracted and broken down into segments by restriction enzymes, such segments are recombined with **cloning vector** (like plasmid or bacteriophage or cosmid or phagemid, etc.) to form a hybrid or recombinant DNA (with the help of ligase). This recombinant DNA is inserted into bacterial cell where it replicates and produces a large number of copies. These identical copies constitute **gene library** (clone—multiple identical copies produced from single origin).

- (Among higher plants, Ti plasmid of *Agrobacterium tumefaciens* and Ri plasmid of *A. rhizogenes* are the best known vectors).

cDNA library

Complementary DNA (cDNA) libraries are prepared from m-RNA by using reverse transcriptase enzyme.

Polymerase Chain Reaction (PCR)/Gene amplification

This technique was developed by **Kary Mullis** of California in 1983 to amplify a specific DNA fragment of interest. In this technique, a single region of DNA, which may be present in vanishingly small amounts, can be amplified cheaply and rapidly. K. Mullis got the Nobel Prize in 1993 (in chemistry) for this work.

- This technique is nicknamed as **'People choice reaction'.** The principle behind this technique is simple—take a piece of double stranded DNA and separate the strands by heating and copy a selected portion of them into DNA; repeat the process over and over (copy the copies) and this gives an exponential increase in copy numbers. The section to be amplified on longer piece of DNA is selected by using primers for the DNA synthesis.
- PCR takes place in **Eppendorf tube.**
- In PCR, **Taq polymerase** enzyme (thermostable) is used in place of ordinary DNA polymerase. Taq polymerase is a DNA polymerase isolated from *Thermus aquaticus* (thermophillic bacterium), growing in hot springs. This enzyme acts best at 72°C.
- In PCR, automatic PCR **thermal cycler** is used, which has a microprocessor controlled temperature cycling needed in PCR for amplification of DNA sequences of interest at a rapid speed (heat stable DNA polymerases, *i.e.*, Taq polymerase avoids the necessity of adding more enzyme after each round of copying).
- Practical limit of length of DNA that can be amplified in this technique was about two Kilobases, but recent techniques have enabled amplification of upto 35 Kb.

The DNA copies obtained in PCR can be used for different purposes, *i.e.*, in forensic science, diagnosis of fetal genetic abnormalities and also used extensively in biochemical research.

Molecular probes (DNA or RNA probes)

These are the small DNA or RNA segments of known sequence that recognize complementary sequence in DNA or RNA.

These probes allow identification and isolation of these specific DNA sequences from an organism.

Blotting pattern

When genomic DNA (of plant or animal) is digested with a restriction enzyme, it is cleaved into segments. The segments of different sizes can be separated through **gel electrophoresis** (usually Agarose gel and Polyacrylamide gels are used). To find similarity of these separated segments with known molecular probe, it is possible to hybridize these segments (bands) with lebelled molecular probe. To facilitate this hybridization, these bands are transferred to a nitrocellulose membrane through a technique called **blotting.** When DNA segments are transferred from gel to nitrocellulose membrane, it is called **Southern blotting** (after the name of E.M. Southern) and when RNA and protein bands are transferred, it is called **Northern blotting** and **Western blotting** respectively (jargon names).

DNA fingerprinting

This technique was developed by Alec Jeffrey (1986) at Leicester University in UK.

- Indian expert of this technique is Lalji Singh (Deptt. of DNA fingerprinting, Hyderabad).

In this technique, DNA isolated from blood stains, hair roots or semen stains is subjected to Southern blotting and DNA hybridization with DNA probes. This reveals polymorphism in DNA..

Each of us is genetically unique (except identical twins) and genetical variations are used in identifying the individuals like that of conventional fingerprint.

- The genome of every human cell contains scattered short highly repeated sequence called **mini-satellite** or **Variable Number Tandem Repeat (VNTR)** of 11 to 16 bp. Their location and repetition is so unique that no two individuals are alike (possibility of similarity is 1 in 10 billion; world population at present is 6 billion).

RFLP (Restriction Fragments Length Polymorphism)

Recognised sites by Restriction Enzymes

These are the sequences of DNA useful for gene mapping and DNA fingerprinting.

DNA fingerprinting is very helpful in disputes of parentage and forensic studies.

Some other important points

- **Southern blotting technique** is used for **isolation of genes**, which was developed by a British worker **E.M. Southern.**
- Artificial synthesis of gene for alanyl t-RNA was done by **Dr. H.G. Khorana** (1968) and he was awarded **American Presidential Award** for this work.
- Gene for tyrosine t-RNA (in *E. Coli*) was artificially synthesized by **Dr. H.G. Khorana.**

Technique & its Practice

GENOMICS: PRINCIPLES AND APPLICATIONS

'Genomics' is a new field of research in biology and it involves **genome-wide studies**. Plant genomics is the latest discipline in the field of plant biotechnology. The term 'genome' had been basically used for basic or haploid set of chromosomes in a diploid organism. But in recent years, the term genome is being used in both diploid and polyploid organisms to describe the **haploid (1C) nuclear DNA** (nuclear genome), **mitochondrial DNA** (mitochondrial genome) or **chloroplast DNA contents** (chloroplast genome). Due to availability of new tools and techniques in recent years (starting from mid-1990s), genomics or genome-wide studies in higher plants and animals have been extensively made. DNA chips (microarrays), mass spectrometry, automatic sequencers, etc., are the newer tools that made genomics studies possible in recent years.

- In classical genetics, we were interested to identify 'genes for functions', whereas in genomics studies, we like to identify 'functions for genes', *i.e.*, an area truly representing **'reverse genetics'**. The genomics research may be undertaken either at structural level or at functional level and the information obtained and technology developed through this type of studies can be used for improvement of crop plants and livestocks and also for human health care.
- Genomics studies or research is classified into three classes:
  - (a) **Structural genomics**, which involves mapping, sequencing and analysis of genomes.
  - (b) **Functional genomics**, which relates the information obtained from structural genomics to a variety of functions, *i.e.*, to identify and study the expression of every gene of a plant genome.
  - (c) **Application genomics**, which involves the use of information obtained from structural and functional genomics to a variety of purposes, *e.g.*, for crop improvement.

  Some progress has been made in structural genomics at international level, while efforts in the field of functional and application genomics are only in preliminary stages (or have just been initiated).
- Plant systems are better suited to derive benefit from genomics research because:
  - (a) Genetic engineering technology in plants is well established and transgenic plants are routinely produced, leading to commercial exploitation of the genetically modified crops.
  - (b) It is possible to introduce any gene in one or more crops and study its expression under the control of a number of regulatory sequences.
  - (c) Facilities for commercialization of transgenic crops are available and the introduced genes can be introgressed into existing high yielding varieties.
  - (d) A model system is available in a non-crop plant *Arabidopsis thaliana*, which is genetically as complex as maize, rice, cotton, wheat, etc.
- The sequencing of genomes is progressing at a fast speed at international level. Several microbial genomes including those of *E. coli*, *Saccharomyces cerevisiae* (budding yeast) and a nematode *Coenorhabditis elegans*, have already been sequenced. Currently, genome-wide sequencing is being carried out in 71 prokaryotic genomes, 12 single celled eukaryotic genomes and 7 complex eukaryotic genomes including those of fruitfly, rice and human being. This number might have gone up during the last one year. Among plant systems, complete genome of *Arabidopsis* (130 Mb) has already been sequenced (as has been published in December 2000) and that of rice (~ 430 Mb) is being sequenced and will be completed by the year 2003. In any individual crop, when complete genome sequence is available, it will be utilized for gene identification through a comparison with available sequence databases (mainly EST databases) and it is the simplest way to find functions of genes (a truly 'reverse genetics' approach). In an angiosperm, the number of genes ranges from 25,000–50,000.

This genomics study will have great impact on all areas of botany, especially in the fields of cell biology, genetics, cyto-genetics and plant breeding, microbiology and plant pathology. This knowledge from genomics research will be used for detection, isolation and manipulation of genes in a variety of crops and hence the scope of production of wonderful transgenic crops (genetically modified crops) will be greatly increased. But the complexity of plant system may resist all these approaches.

To make genomics research possible, expensive investments (billions of US dollars) are being made by the private and public sector (particularly in USA). Other countries are also trying to keep pace with these developments. In India, the prospects of plant genomics research are dismal due to the huge investments needed for research in this area. But we can certainly get the benefits from the enormous databases available on websites.

The Human genome

The human genome is more than 25 times the size of the previously sequenced genomes of *Drosophila* and *Arabidopsis* and it is eight times the sum of all previously sequenced genomes. The complete sequence of the first human chromosome—small chromosome 22—was published in December 1999 and complete sequence of human chromosome 21 followed in May 2000.

- As a result of sequence of human genome, there appears to be only about **30,000 to 35,000** genes rather than the estimated 50,000 to 120,000 genes suggested by earlier studies. It has been planned by leaders of Public Human Genome Project to complete the sequence of human genome by 2003.

MULTIPLE CHOICE QUESTIONS

1. Nucleic acid (nuclein) was first discovered by:
(a) Hershey and Chase (b) Avery
[✓ (c) Meischer] (d) Conrat

2. Genetic material of most of the organisms is:
[✓ (a) DNA] (b) RNA
(c) Nucleoproteins (d) None of these

3. All the cells of organism have same amount of DNA was first reported by:
(a) Mirsky and H. Ris (b) Avery and McLeod
(c) Hershey and Chase (d) Griffith

4. Strong evidence in favour of DNA as genetic material comes from: (CET J&K 2003)
(a) Constancy of DNA
(b) Staining with feulgen
[✓ (c) Transformation experiment in bacteria]
(d) None of the above

5. RNA as genetic material in plant viruses was shown by:
(a) Hershey (b) McLeod and Avery
[✓ (c) Fraenkal Conrat] (d) None of these

6. The monomeric units of DNA are: (CET MH 2003)
(a) Proteins (b) Nucleosides
[✓ (c) Nucleotides] (d) Purines and pyrimidines

7. The sugar present in DNA is:
(a) Hexose sugar (b) Triose sugar
(c) Tetrose sugar [✓ (d) Pentose sugar]

8. Purines are:
(a) Single ringed nitrogenous compounds
[✓ (b) Two ringed nitrogenous compounds]
(c) Three ringed nitrogenous compounds
(d) All of the above

9. Which of the following is a pyrimidine base?
(a) Adenine [✓ (b) Cytosine]
(c) Guanine (d) None of these

10. 2,6-oxy, 5-methyl pyrimidine is:
(a) Adenine (b) Guanine
(c) Cytosine (d) Thymine

11. The adjacent nucleotides in DNA are joined by:
(a) Ionic bond (b) H-bond
(c) Phosphodiester bond (d) Disulphide bond

12. Double helical model of DNA was given by: (CET J&K 2002)
(a) Wilkins (b) Franklin
[✓ (c) Watson and Crick] (d) None of these

13. Double helix model of DNA was given in:
(a) 1962 (b) 1952
[✓ (c) 1953] (d) 1963

14. Diameter of DNA is about:
(a) 24 Å [✓ (b) 20 Å]
(c) 34 Å (d) 30 Å

15. Double helix DNA of Watson and Crick is:
(a) Left handed coiled [✓ (b) Right handed coiled]
(c) Zig-zag (d) None of these

16. Normal type of DNA is called:
[✓ (a) B-DNA] (b) Z-DNA
(c) C-DNA (d) None of these

17. Movement of DNA between mitochondria, chloroplast and nucleus constitutes:
(a) Satellite DNA (b) Repetitive DNA
(c) Transposon (d) Promiscuous DNA

18. Which N-base is present in RNA and not in DNA? (CET J&K 2002, 2003)
(a) Adenine (b) Cytosine
(c) Guanine (d) Uracil

19. RNA is generally having:
(a) Single polynucleotide chain
(b) Two polynucleotide chains
(c) Three polynucleotide chains
(d) None of the above

20. The two strands of DNA are:
(a) Similar in nature and complementary
[✓ (b) Antiparallel and complementary]
(c) Dissimilar and non-complementary
(d) Antiparallel and non-complementary

21. Short-lived RNA is:
(a) t-RNA (b) r-RNA
[✓ (c) m-RNA] (d) All of these

22. Name m-RNA was given by:
[✓ (a) Jacob and Monod] (b) Beadle and Tatum
(c) McLeod and McCarty (d) None of these

23. Which is called soluble RNA?
(a) m-RNA [✓ (b) t-RNA]
(c) r-RNA (d) None of these

24. Which is the smallest molecule of RNA? (MPPMT 2002)
(a) m-RNA [✓ (b) t-RNA]
(c) r-RNA (d) None of these

25. Which type of RNA contains unusual bases? (CPMT 1990)
(a) m-RNA [✓ (b) t-RNA]
(c) r-RNA (d) None of these

26. The distance between two bases of a DNA molecule is: (Haryana PMT 2001)
[✓ (a) 3·4 Å] (b) 4·3 Å
(c) 4·43 Å (d) 6·8 Å

27. Maximum proportion of which type of RNA is present in cell? (Jharkhand CECE 2003)
(a) m-RNA (b) t-RNA
[✓ (c) r-RNA] (d) None of these

28. Deoxyribose sugar and N-base together constitute: (AMU 2003)
(a) Nucleotide [✓ (b) Nucleoside]
(c) DNA (d) None of these

29. In a nucleotide, N-base is attached to sugar at:
[✓ (a) C-1] (b) C-2
(c) C-5 (d) C-3

30. Adjacent nucleotides are joined together by a bond between:
(a) Carbon-1 of deoxyribose sugar of one nucleotide and C-5 of sugar of second nucleotide
(b) C-2 and C-5
[✓ (c) C-3 and C-5]
(d) None of the above

31. Watson and Crick got Nobel Prize along with Wilkins and Franklin in:
(a) 1952 (b) 1953
[✓ (c) 1963] (d) 1962

32. In Z-DNA, pitch of the turn and number of base pairs per turn are:
(a) 34 Å, 10 base pairs (b) 34 Å, 12 base pairs
(c) 45 Å, 10 base pairs (d) 45 Å, 12 base pairs

33. Clover leaf model of t-RNA was given by:
(a) Khorana (b) Nirenberg
(c) Holley (d) None of these

34. What is base sequence of alanyl t-RNA at 3′ end and 5′ end respectively?
(a) G, GCC (b) A, ACC
(c) G, CCA (d) CCA, G

35. The molecular weight of t-RNA molecule is:
(a) 5,00,000-10,00,000 (b) 40,000-10,00,000
(c) 25,000-30,000 (d) None of these

36. Double stranded RNA is present in:
(a) All plant viruses (b) All animal viruses
[✓ (c) Reoviruses] (d) All plants

37. Replication of DNA is:
(a) Conservative [✓ (b) Semiconservative]
(c) Destructive (d) None of these

38. If tritiated thymidine (H^3-tdR) is present in both strands of DNA, what will be the number of molecules of DNA having H^3-tdR after 3 replications (duplication)?
(a) 8 (b) 6
(c) 4 (d) 2

39. Semiconservative mode of DNA replication was supported experimentally by: **[BCECE (P.T. Exam.) 2002]**
[✓ (a) Meselson] (b) Taylor
(c) Cairns (d) All of these

40. In replication, new DNA strand is formed (synthesized) in? **(MPPMT 2001)**
(a) 3′→5′direction [✓ (b) 5′→3′direction]
(c) Both (a) and (b) (d) None of these

41. Enzymes involved in DNA replication are:
(a) RNA-polymerase and DNA-polymerase
(b) RNA-polymerase and ligase
[✓ (c) DNA-polymerase and polynucleotide ligase]
(d) DNA-polymerase

42. 'Okazaki' segments are:
(a) Segments of DNA capable of replication
(b) Segments of a chain of nucleotides formed during replication of DNA
(c) Segments of a chain of nucleotides formed during transcription
(d) Segments of gene which undergo recombination

43. Which of the following elements is not present in a nitrogenous base?
[✓ (a) P] (b) N
(c) C (d) H

44. Which of the following is a base analogue?
(a) Nitrous acid (b) Colchicine
(c) Acridine (d) BudR

*45. Which is base analogue of adenine?
(a) 5-bromo uracil (b) 2-amino purine
(c) Bromodeoxyuracil (d) None of these

46. Two strands of DNA are bound by:
(a) Hydrogen (b) Oxygen
(c) Carbon (d) Nitrogen

47. In DNA, guanine pairs with: **(St. Jones 2002)**
(a) Thymine (b) Cytosine
(c) Adenine (d) Uracil

48. The functional genetic unit is: **(MPPMT 2001)**
(a) Gene (b) Chromosome
(c) DNA (d) Cistron

*49. The nucleic acid as the infective part of viruses was proved by:
(a) Hershey and Chase (b) Fraenkal Conrat
(c) Khorana (d) Kornberg

50. Which sequence is according to increasing molecular weight?
(a) t-RNA, DNA, m-RNA, r-RNA
(b) r-RNA, DNA, t-RNA, m-RNA
(c) DNA, m-RNA, r-RNA, t-RNA
(d) t-RNA, r-RNA, m-RNA, DNA

51. DNA replication is:
(a) Continuous [✓ (b) Semi discontinuous]
(c) Discontinuous (d) None of these

52. The strand of DNA, on which the synthesis of DNA occurs discontinuously is called:
(a) Leading strand (b) Discontinuous strand
(c) Lagging strand (d) Complementary strand

53. In a DNA molecule:
(a) $A{=}T$ and $C{\equiv}G$ (b) $A{=}G$ and $T{=}C$
(c) $A{=}U$ and $T{\equiv}C$ (d) $A{-}T$ and $C{\equiv}G$

54. Genes are made of:
(a) Histones (b) Lipoproteins
(c) Hydrocarbons (d) Polynucleotide

55. Genes are located on the chromosome in a .... manner:
(a) Spiral (b) Ovate
(c) Linear (d) Scattered

56. The smallest element or sub-division of a gene which can be affected by mutation is:
(a) Interferon (b) Recon
(c) Muton (d) Cistron

57. 'One gene one enzyme' concept was put forward by:
(a) Lederberg and Tatum (b) Zinder and Lederberg
(c) Beadle and Tatum (d) Kornberg and Tatum

58. Nobel prize for artificial synthesis of DNA (gene) was given to:
(a) Nirenberg (b) Ochoa
(c) Kornberg (d) Khorana

59. Nobel Prize for *in vitro* synthesis of polyribonucleotides was given to:
(a) Nirenberg (b) Kornberg
(c) Ochoa (d) Khorana

60. Who discovered DNA-ligase enzyme?
(a) Khorana (b) Nirenberg
(c) Robert Holley (d) None of these

61. Transfer of genetic information from DNA to m-RNA is called: (MPPMT 2002)
(a) Replication (b) Translation
(c) Transcription (d) Transamination

62. Which is called 'Central Dogma'? (AMU 2003)
(a) DNA → m-RNA ⇄ Protein
(b) DNA ⇆ m-RNA → Proteins
(c) DNA → m-RNA → Protein
(d) None of the above

63. Reverse transcription was discovered by:
(a) Conrat (b) Temin and Baltimore
(c) Hershey and Chase (d) Nirenberg and Matthaei

*64. Synthesis of DNA on RNA template was shown first in:
(a) Wound tumour virus (b) Rous sarcoma virus
(c) *E. coli* bacteria (d) None of these

65. 'Operon Model' as a controlling mechanism in bacteria was given by: (Orissa JEE 2003)
(a) Nirenberg (b) Kornberg
(c) Holley (d) Jacob and Monod

66. 'Operon' is made of:
(a) Structural genes
(b) Regulator, promotor and operator genes
(c) Structural genes and associated control genes
(d) None of the above

67. The repressor molecules which unite with operator gene to stop transcription are produced by:
(a) Regulator gene (b) Promotor gene
(c) Inducer gene (d) Structural gene

68. The term 'Gene' was introduced by: (Orissa JEE 2003)
(a) Benzer (b) Jacob
(c) Johannsen (d) Kornberg

69. Beadle and Tatum gave his 'one gene one enzyme' theory, while he was working on:
(a) *E. coli* (b) *Drosophila*
(c) Red mould (d) *Acetabularia*

70. A species of *Neurospora* which cannot grow on a simple minimal medium is called:
(a) Auxotroph (b) Prototroph
(c) Heterotroph (d) Autotroph

71. Phenylketonuria is due to:
(a) Absence of an enzyme
(b) Absence of one chromosome
(c) Presence of one more gene
(d) None of the above

72. The terms cistron, muton and recon were given by:
(a) Jacob and Monod (b) Kornberg and Khorana
(c) Seymour Benzer (d) Beadle and Tatum

73. If DNA is heated at 80°C for 15 minutes, what will happen?
(a) Nucleotides separate
(b) H-bonds between two chains (strands) break
(c) Breaks into thousands of pieces
(d) Nothing will happen

*74. If the number of amino acids in a polypeptide chain is 100, what will be the number of nucleotides in its cistron?
(a) 100 (b) 300
(c) 400 (d) 200

75. Artificial synthesis of gene for alanine t-RNA was done by:
(a) Kornberg (b) Nirenberg
(c) Khorana (d) None of these

76. Number of base pairs in alanyl t-RNA is:
(a) 95 (b) 75
(c) 77 (d) 90

77. The DNA segments causing illegitimate recombination are called:
(a) Retroposons (b) Transposons
(c) Pseudogenes (d) Split genes

78. The term 'Transposon' was first used by:
(a) Barbara McClintock (b) Hedges and Jacob
(c) Rogers (d) None of these

79. The jumping genes (controlling elements) were first of all discovered in .... by McClintock: (Haryana PMT 2001; B.V. Pune 2003)
(a) Mice (b) Corn
(c) Fruit fly (d) Snap dragon

80. The DNA segments which have RNA origin are called:
(a) Mobile genetic elements (b) Satellite DNA
(c) Repetitive DNA (d) Retroposons

81. 'Exons' and 'Introns' are present in:
(a) Transposons (b) Retroposons
(c) Interrupted genes (d) None of these

82. Information pieces of split gene are:
(a) Exons (b) Introns
(c) Pseudogenes (d) Cistrons

83. Who discovered 'Genetic Code'?
(a) Kornberg and Matthaei
(b) Nirenberg and Matthaei
(c) F.H.C. Crick
(d) Nirenberg, Khorana and Holley

84. Multiple coding system of genetic code is called:
(a) Commaless G. code (b) Overlapping G. code
(c) Ambiguous G. code (d) Degenerate G. code

85. The triplet nature of genetic code was proposed by:
(a) Matthaei (b) F.H.C. Crick
(c) Nirenberg (d) None of these

86. Chain initiation codon is: (MPPMT 2001; EAMCET 2003)
(a) UGA [✓ (b) AUG]
(c) GUG [✓ (d) AUG or GUG]

87. Which of the following is nonsense (chain termination codon)? (CET J&K 2003)
(a) AUG [✓ (b) UAA]
(c) GUG (d) ACG

88. Delineation of genetic code was done by:
(a) Nirenberg and Matthaei
(b) Nirenberg, Khorana and R. Holley
(c) F.H.C. Crick
(d) Gamov

89. The technique used for isolation of genes is:
(a) Eastern blotting (b) Northern blotting
(c) Southern blotting (d) None of these

90. The RNA specially responsible for proper sequence of amino acid in protein synthesis is:
(a) r-RNA (b) m-RNA
(c) t-RNA (d) Chromosomal RNA

91. Synthesis of any protein in a cell is determined by:
(a) Types of ribosomes
(b) Mitochondria
(c) Sequence of nucleotides in DNA
(d) Sugar and phosphate of DNA

92. Genes control:
(a) Heredity but not protein synthesis
(b) Protein synthesis but not heredity
(c) Protein synthesis and heredity
(d) Biochemical reactions of some enzymes

93. Extranuclear DNA is found in:
(a) Golgi apparatus (b) Chloroplast
(c) Ribosomes (d) Endoplasmic reticulum

94. Eukaryotic DNA can be distinguished from prokaryotic DNA on the basis of:
(a) Eukaryotic DNA is much more per cell
(b) Eukaryotic DNA has more stable average G-C content
(c) Eukaryotic DNA is typically non-homologous
(d) All of the above

95. Nucleic acids are found in:
(a) Cytoplasm
(b) Nucleus
(c) Both cytoplasm and nucleus
(d) Nucleus and ribosomes

*96. Instead of chromosome which of the following has only DNA?
(a) *Anabaena* and *E. coli*
(b) *Volvox*
(c) *Chlamydomonas*
(d) *Plasmodiophora* and *Cystopus*

97. DNA and RNA are similar in having:
(a) Similar pyrimidines
(b) Similar sugars
(c) Both are polymers of nucleotides
(d) Both are double stranded

*98. Transcriptional gene is controlled by:
(a) Heterochromatin (b) Euchromatin
(c) Both (a) and (b) (d) None of these

99. The informational molecules which carry hereditary information from generation to generation are:
(a) Polysaccharides (b) Polypeptides
(c) Polynucleotides (d) All of these

100. Which of the following base is found only in RNA and not in DNA? (MPPMT 2001)
(a) Guanine (b) Thymine
(c) Uracil (d) Adenine

*101. How many nucleotides are present in a molecule of DNA having 120 adenine and 120 guanine bases?
(a) 240 (b) 480
(c) 60 (d) 120

102. There are:
(a) Six types of RNA (b) Four types of RNA
(c) Five types of RNA (d) Three types of RNA

103. DNA is not directly involved in the synthesis of:
(a) Protein molecule (b) Another DNA molecule
(c) t-RNA molecule (d) None of these

104. DNA does not contain:
(a) Adenine (b) Thymine
(c) Uracil (d) Cytosine

105. The m-RNA is formed:
(a) In the nucleus
(b) By free ribosomes
(c) From the ribosome on endoplasmic reticulum
(d) From DNA in nucleus

106. Meselson and Stahl used which technique to demonstrate semiconservative mode of replication of DNA?
(a) Ultracentrifugation (b) Auto-radiography
(c) Both (a) and (b) (d) None of these

107. Pyrimidines of RNA are represented by:
(a) Thymine and cytosine (b) Adenine and cytosine
(c) Uracil and cytosine (d) Adenine and guanine

108. In the process of transcription, what happens?
(a) A polypeptide chain is synthesized
(b) RNA molecule is synthesized within a ribosome
(c) RNA molecule is synthesized on DNA template
(d) DNA molecule is synthesized on a DNA

109. In Griffith experiment, mice injected with mixture of heat killed S-type bacteria and living R-type bacteria were killed because:
(a) Living R-type bacteria change into S-type
(b) Heat killed S-type bacteria were rejuvenated
(c) Both (a) and (b)
(d) None of the above

*110. How many out of 64 possible triplet codons, code for amino acids?
(a) 63 (b) 64
(c) 62 (d) 61

111. RNA is absent in:
(a) Plasmalemma (b) Cytoplasm
(c) Ribosomes (d) Chromosomes

112. The enzyme which is responsible for breaking and resealing a strand of DNA during replication is:
(a) Ligase (b) Topoisomerase
(c) Endonuclease (d) Helicase

113. Strands of DNA are bound by:
(a) Hydrogen bonds (b) Phosphate diester bonds
(c) Covalent bonds (d) Ionic bonds

114. Enzyme peptidyl transferase helps in:
(a) Shifting of ribosomes on m-RNA
(b) Transferring amino group from one amino acid to another
(c) Removal of t-RNA after formation of peptide bond between amino acids
(d) Catalysing bonding between adjacent amino acids

115. The process by which DNA of the nucleus passes genetic information to m-RNA is called:
(a) Transcription (b) Transportation
(c) Translocation (d) Translation

116. During replication, DNA synthesis occurs discontinuously on one strand because:
(a) DNA molecule uncoils gradually
(b) Hydrogen bonds keep the two strands together

(c) Topoisomerases and helicases can act only on one side of molecule
(d) DNA polymerase enzyme can polymerise the nucleotides in only one direction

117. Who among the following scientists developed cytochemical technique for the presence of DNA?
(a) Johannsen (b) Feulgen and Rossenbeck
(c) McClintock (d) Hammerling

118. C-value means:
(a) Haploid DNA content in an individual
(b) Colchicine treatment value
(c) Gene binding frequency on chromosome
(d) None of the above

119. Duplication of DNA is called:
(a) Transduction (b) Transcription
(c) Translation (d) Replication

120. Enzyme responsible for breaking DNA strand at an internal position is:
(a) Exonuclease (b) Endonuclease
(c) DNA-polymerase (d) DNA-polymerase II

121. Nucleoproteins most probably provided the:
(a) Life (b) Sugars
(c) Amino acids (d) Soil

122. Watson and Crick are credited for finding:
(a) DNA is carrier of genetic information
(b) DNA is double strand helix
(c) RNA is double strand helix
(d) DNA is composed of sugar, phosphoric acid and nitrogenous bases

123. Sex cells generally possess: (AMU 1991)
(a) Half the amount of DNA as the body cells
(b) Half the amount of RNA as the body cells
(c) The same amount of DNA as the body cells
(d) Twice the amount of DNA as the body cells

124. A ribose (but not deoxyribose) nucleotide is:
(a) Cytosine-pentose sugar-phosphate
(b) Guanine-pentose sugar-phosphate
(c) Thymine-pentose sugar-phosphate
(d) Uracil-pentose sugar-phosphate

125. DNA generally acts as a template for the synthesis of:
(a) Only protein (b) Only DNA
(c) Only RNA (d) Both DNA and RNA

126. Nobel Prize to Dr. H.G. Khorana was given in:
(a) 1962 (b) 1953
(c) 1968 (d) 1942

127. RNA serves an important role in: (CPMT 1991)
(a) Carbohydrate synthesis (b) Protein synthesis
(c) Fat synthesis (d) None of these

***128.** DNA strands are antiparallel because of:
(AIIMS 1990; MPPMT 2001)
(a) Hydrogen bonds (b) Disulphide bonds
(c) Phosphate diester bonds (d) None of these

129. Ribosomes consist almost entirely of:
(a) Protein and RNA
(b) Protein and DNA
(c) RNA and DNA
(d) Protein, RNA and amino acids

130. In genetic engineering for cutting DNA segment, which of the enzyme is used? (BHU 1991)
(a) Restriction nuclease (b) Ligase
(c) DNA polymerase (d) ATPase

131. Enzyme used for unwinding of DNA molecule is:
(a) Helicase (b) Unwindase
(c) Polymerase (d) Topoisomerase

132. First m-RNA codon discovered by Nirenberg and Matthaei is:
(a) UAA (b) UGA
(c) UCC (d) UUU

133. Nucleotide is: (CPMT 1992)
(a) Base, sugar and OH
(b) Base, sugar and phosphate
(c) (Base, sugar and phosphate)$_n$
(d) Sugar and phosphate

134. The first triplet codon discovered UUU codes for:
(a) Methionine (b) Phenyl alanine
(c) Tryptophan (d) Nonsense codon

135. Which site a t-RNA molecule hydrogen bonds to a m-RNA molecule?
(a) Codon
(b) Anticodon
(c) 5′-end of the t-RNA molecule
(d) 3′-end of a t-RNA molecule

136. An antibiotic which inhibits the synthesis of RNA especially in regions which are rich in cytosine and guanine is: (BHU 1993)
(a) Actinomycin (b) Chloramphenicol
(c) Mitomycin (d) Puromycin

137. In DNA 10% guanine is present. How much thymine is present? (EAMCET 1993)
(a) 10% (b) 40%
(c) 80% (d) 20%

138. Experiments using N^{15} (heavy nitrogen) to confirm the semiconservative replication of DNA were carried out by: (MPPMT 1993)
(a) Meselson and Stahl (b) Hershey and Chase
(c) Beadle and Tatum (d) Watson and Crick

139. DNA consists of two complementary nucleotide chains. If the sequence of nucleotides in one of the chains is AGCTTCGA, then the nucleotide sequence in the other chain shall be:
(a) TAGCATAT (b) GATCCTAG
(c) TCGAAGCT (d) GCTAAGCT

140. In DNA the base pairing occurs as: (MPPMT 1995)
(a) Thymine with adenine and cytosine with cytosine
(b) Adenine with thymine and cytosine with guanine
(c) Thymine with cytosine and guanine with adenine
(d) Adenine with cytosine and guanine with thymine

141. DNA is present in: (MPPMT 1995)
(a) Nucleus only (b) Mitochondrion only
(c) Chloroplast only (d) All of these

142. A nucleoside differs from a nucleotide in not having: (MPPMT 1995)
(a) Phosphate (b) Sugar
(c) Nitrogen base (d) Phosphate and sugar

143. Watson and Crick are known for their discovery that DNA: (MPPMT 1995)
(a) Is a single stranded helix
(b) Contains deoxyribose only
(c) Is a double stranded helix
(d) Synthesis r-RNA

144. A nucleoside is: [BHU 1995; BCECE (P.T. Exam.) 2001]
(a) Base + sugar (b) Base + phosphate
(c) Sugar + phosphate (d) Base + sugar + phosphate

145. Circular DNA is present in:
(a) Chloroplast of an eukaryotic cell
(b) Blue-green algae
(c) Virus
(d) Fungus

146. Gene is:
(a) A segment of DNA
(b) A segment of DNA and histone
(c) A segment of DNA, RNA and histone
(d) All of the above

147. Nobel prize to Dr. H.G. Khorana was given for:
(a) Artificial synthesis of gene for alanyl t-RNA
(b) DNA-ligase discovery
(c) Telling base sequence of alanine t-RNA
(d) All of the above

148. Distance between the strands of DNA is:
(a) 3·4 Å (b) 3 Å
(c) 12 Å (d) 20 Å

149. The function of t-RNA is:
(a) Selection of amino acids
(b) Production of m-RNA
(c) Production of ribosomes
(d) Production of microsomes

150. Which of the following is capable of self-replication?
(a) An enzyme (b) A carbohydrate molecule
(c) A water molecule (d) A nucleic acid

151. Which of the following statements is not consistent with the double helical model of DNA? (CBSE 1990)
(a) The amount of A + T/C + G is not constant in different organisms
(b) Density decreases on heating
(c) A = C, C = G
(d) According to X-ray diffraction, it is a double helical structure

152. Replication of DNA in eukaryotes commences from: (BHU 1990)
(a) One end of the chromatid extending to the other end
(b) Both ends of the chromatid simultaneously
(c) The centromere to either of the ends of chromatids
(d) Several sites along the DNA of the chromatid simultaneously

153. The correct statement is that: (Re. Ex. CPMT 1991)
(a) RNA is double stranded
(b) RNA is single stranded
(c) Most cellular RNA is single stranded
(d) Both double and single RNA's are present in equal amounts

154. Enzyme necessary for transcription is:
(a) DNA polymerase (b) RNA polymerase
(c) Endonuclease (d) RNAase

155. If the DNA codons are ATG ATG ATG and a cytosine base is inserted at the beginning, which of the following will result? (CBSE 1995)
(a) A nonsense mutation (b) CAT GAA TGA TG
(c) CAT GAT GAT G (d) C ATG ATG ATG

156. Amino acid binding site in t-RNA is: (CET Karnataka 1997)
(a) CCA 3′ end (b) DHU loop
(c) 5′ end (d) Anticodon loop

157. Semiconservative mode of replication of DNA was first proved experimentally by: (CET Chandigarh 1997; BHU 1997)
(a) Taylor *et al.* (b) Watson and Crick
(c) Messelson and Stahl (d) Alexander Rich

158. The operator gene of lac operon is "turned on" when lactose molecules bind to: (CET Karnataka 1997)
(a) m-RNA (b) Promotor site
(c) Repressor protein (d) Operator gene

159. Which of the following has single ring structure? (Pb. PMT 1997)
(a) Uracil (b) Thymine
(c) Adenine (d) Guanine

160. In an experiment it is found that adenine constitutes 31% and guanine 40%. The quantity of cytosine in the DNA is likely to be: (Pb. PMT 1997)
(a) 19% (b) 40%
(c) 31% (d) 50%

161. In a double stranded DNA molecule the percentage of cytosine is 18. What is the percentage of Adenine? (CET Karnataka 1997)
(a) 32% (b) 64%
(c) 36% (d) 18%

162. DNA synthesis can be specifically measured by estimating the incorporation by radio labelled: (CBSE 1997)
(a) Uracil (b) Adenine
(c) Thymidine (d) Deoxyribose sugar

163. Genes located on mitochondrial DNA: (CBSE 1997)
(a) Generally show maternal inheritance
(b) Are always inherited from the male parent
(c) Show biparental inheritance like the nuclear gene
(d) All not inherited

164. Which is nucleotide? (CPMT 1997)
(a) Sugar-purine-phosphate
(b) Sugar-purine-pyrimidine-phosphate
(c) Sugar-phosphate
(d) Sugar-purine pyrimidine

165. Replication is: (CPMT 1997)
(a) DNA → DNA (b) DNA → RNA
(c) RNA → DNA (d) RNA → RNA

166. Prokaryotic DNA is: (CPMT 1997)
(a) Double stranded round
(b) Single stranded round
(c) Double stranded straight
(d) None of the above

167. Which of the following serves as a terminal codon? (CBSE 1996)
(a) AUG (b) GCG
(c) UAG (d) AGA

168. Which type of DNA is found in bacteria? (CBSE 1996)
(a) Straight DNA (b) Helical DNA
(c) Membrane bound DNA (d) Circular free DNA

169. Polygenic genes show: (CBSE 1996)
(a) Different phenotypes (b) Different genotypes
(c) Both (a) and (b) (d) None of these

170. The hereditary material present in the bacterium *E. coli* is: (CBSE 1997)
(a) Single stranded DNA (b) DNA
(c) Double stranded DNA (d) RNA

171. The codons causing chain termination are: (CBSE 1997)
(a) TAG, TAA, TGA (b) GAT, AAT, AGT
(c) AGT, TAG, UGA (d) UAG, UGA, UAA

172. The RNA that picks up specific amino acid from amino acid pool in the cytoplasm to ribosome during protein synthesis is called: (CBSE 1997; AIIMS 1998)
(a) m-RNA (b) t-RNA
(c) r-RNA (d) RNA

173. Which of the following is used in recombinant DNA technology? (MPPMT 1997)
(a) DNA polymerase I
(b) Nucleases
(c) Restriction endonucleases
(d) DNA polymerase I, II and III

174. A vector is used to carry foreign DNA in genetic engineering. Which one of the following is used as a vector? (AFMC 1997)
(a) Plasmid (b) Viruses
(c) Phage (d) All of these

175. For their contribution in biochemical genetics the scientists who received the Nobel Prize in 1958 were: (AFMC 1997)
(a) Beadle and Tatum (b) Beadle and Lederberg
(c) Lederberg and Zindes (d) Zinder and Morgan

176. Genes located at the same locus of chromosomes are: (CBSE 1997)
(a) Multiple alleles (b) Polygenes
(c) Oncogenes (d) None of these

177. How many types of RNA polymerase are present in prokaryotic cells?
(a) 0 (b) 2
(c) 3 (d) 1

*178. Which step of translation does not consume a high energy phosphate bond? (CBSE 1997)
(a) Translocation
(b) Amino acid activation
(c) Peptidyl-transferase reaction
(d) Aminoacyl t-RNA binding to A site

179. The process by which altering the code in the DNA sequence, the message is reversed, is: (AFMC 1997)
(a) Deletion (b) Inversion
(c) Translocation (d) None of these

*180. In protein synthesis, the first codon is AUG. The molecule which recognises that codon in prokaryotes during translation is: (AIIMS 1996)
(a) Primer RNA (b) r-RNA
(c) f-met-t-RNA (d) Met-t-RNA

181. Gene is a: (AIIMS 1994)
(a) RNA molecule (b) DNA molecule
(c) Protein molecule (d) DNA histone molecule

182. In eukaryotes after transcription of m-RNA, some of its nucleotides are removed before it is translated into polypeptide. The nucleotides which are removed from m-RNA are called: (CBSE 1997)
(a) Exons (b) Upstream sequences
(c) Unusual bases (d) Introns

183. Taylor conducted his experiments to prove semiconservative DNA or chromosome replication on: (BHU 1997)
(a) *Vinca rosea* (b) *Vicia faba*
(c) *Victoria regia* (d) *Vaucheria hemat*

*184. Ambiguous codon in nature is:
(a) UAG (b) UGA
(c) UAA (d) UUU

185. Nonsense codon, known as 'ochre' is:
(a) UAA (b) UAG
(c) UGA (d) UUU

186. DNA formation takes place by: (CPMT 1998)
(a) Replication (b) Transcription
(c) Translation (d) Transduction

187. In DNA message is written in: (CPMT 1998)
(a) Nucleotide (b) Base
(c) Base pair (d) Protein

188. Transcription takes place with the help of: (CPMT 1998)
(a) DNA polymerase (b) RNA polymerase
(c) DNA ligase (d) Carboxy peptidase

*189. Genes that are involved in turning on or off the transcription of a set of structural genes are called: (CBSE 1998; MPPMT 2001)
(a) Redundant genes (b) Operator genes
(c) Regulatory genes (d) Polymorphic genes

190. DNA elements which can switch their position are called: (CBSE 1998)
(a) Transposons (b) Cistrons
(c) Introns (d) Exons

191. The eukaryotic genome differs from prokaryotic genome because: (CBSE 1998)
(a) The DNA is circular and single stranded in prokaryotes
(b) DNA is complexed with histones in prokaryotes
(c) Genes in former case are organized into operons
(d) Repetitive sequences are present in eukaryotes

*192. Radioactive thymidine when added to the medium surrounding living mammalian cells gets incorporated into newly synthesized DNA. Which of the following types of chromatin is expected to become radioactive if cells are exposed to radioactive thymidine as soon as they enter the S-phase? (CBSE 1998)
(a) Heterochromatin
(b) Euchromatin
(c) Both heterochromatin and euchromatin
(d) Neither heterochromatin nor euchromatin

193. Initiation codon in eukaryotic protein synthesis is: (CBSE 1999, 2000)
(a) CGA (b) GCA
(c) AUG (d) GUA

*194. Prokaryotic genetic material possesses: (CBSE 1999)
(a) Either DNA or histones
(b) Both DNA and histones
(c) Neither DNA nor histones
(d) DNA but no histones

*195. Genes are chemically: (CBSE 1999; BHU 2002)
(a) Lipoproteins (b) Glycoproteins
(c) Histones (d) Polynucleotides

196. Nuclease enzyme is capable of: (CBSE 1999)
(a) Breaking disulphide bond
(b) Removing terminal nucleotide
(c) Breaking all types of bonds
(d) Breaking phosphodiester bond

197. A base pair change: (CBSE 1999)
(a) Always causes amino acid replacement
(b) Always changes protein function
(c) Results in new species
(d) Does not necessarily change the phenotype

198. In inducible operon concept of gene, the regulator gene produces: (CBSE 1999)
(a) Inhibitor (b) Regulator
(c) Repressor (d) Inducer

199. Which process is associated with change in cellular DNA content? (CBSE 1999)
(a) Spore germination (b) Cytokinesis
(c) Fertilization (d) Blastulation

200. Nucleotides in RNA are joined by: (CPMT 1999)
(a) H-bond (b) Phosphodiester bond
(c) Disulphide bond (d) Peptide bond

201. Function of DNA polymerase is: (AIIMS 1999)
(a) Proof reading and editing for correct DNA replication
(b) Unwinding of DNA helix
(c) Union of Okazaki segments
(d) None of the above

202. Anticodon is present on: (CBSE 2000; MPPMT 2002)
(a) m-RNA (b) t-RNA
(c) mt-RNA (d) r-RNA

203. What is the similarity between RNA and DNA? (CBSE 2000)
(a) Both have purines
(b) Both can replicate
(c) Both have same structure
(d) All of the above

204. Coiling in DNA is: (CBSE 2000; MPPMT 2000)
(a) Right handed (b) Zig-zag
(c) Left handed (d) None of these

205. Formation of RNA from DNA is called: (CPMT 2000; CET Karnataka 2000)
(a) Translation (b) Reverse transcription
(c) Transcription (d) Transduction

206. Which base is not found in DNA? (MPPMT 2000)
(a) Guanine (b) Cytosine
(c) Uracil (d) Adenine

207. What is nucleotide? (MPPMT 2000)
(a) Sugar + N-base
(b) Nitrogenous base
(c) Phosphoric acid
(d) Sugar + N-base + Phosphoric acid

208. Non-genetic RNA is of: (MPPMT 2000)
(a) One type (b) Two type
(c) Three type (d) Non-functional type

209. Who proposed the operon model of gene regulation? (MPPMT 2000)
(a) Khorana (b) Monod
(c) Jacob (d) Jacob and Monod

210. If one strand of DNA has the base sequence CAT, GAC, TAG, what would be the base sequence in the other strand? (MPPMT 2000)
(a) GTA, CTG, ATC (b) GAT, GTC, ACT
(c) TAC, ACT, GCT (d) CAT, TAG, GAC

211. How many nucleotides are present in one turn of DNA helix? (MPPMT 2000; Manipal 2001)
(a) 8 (b) 10
(c) 6 (d) 100

212. Which of the following is a nonsense codon? (MPPMT 2000)
(a) DNA (b) GCG
(c) UUU (d) UAG

*213. Who is credited to show that viruses are the cause of cancer? (MPPMT 2000)
(a) Mendel (b) Khorana
(c) Swaminathan (d) Dulbecco

214. Feulgen reaction is employed to detect the presence of: (MPPMT 2000)
(a) DNA (b) RNA
(c) Protein (d) Fat

215. The lac operon concept of *Escherichia coli* was proposed in 1961 by: (CET Karnataka 2000; MPPMT 2001)
(a) Watson and Crick (b) H.G. Khorana
(c) Meselson and Stahl (d) Jacob and Monod

*216. DNA nucleotides are attached by: (AFMC 2001)
(a) Hydrogen bonds (b) Covalent bonds
(c) van der Waals' forces (d) Electrovalent bonds

217. The number of H-bonds that bound guanine and cytosine is: (AFMC 2000)
(a) 4 (b) 3
(c) 2 (d) 1

218. Which of the following sequences is found in *Rous sarcoma* virus? (AFMC 2000)
(a) DNA → DNA → Protein
(b) RNA → DNA → RNA → Protein
(c) RNA → RNA → Protein
(d) DNA → RNA → Protein

219. In genetic engineering, which of the following is used? (AIIMS 2001)
(a) Plastid (b) Plasmid
(c) Mitochondria (d) Golgi bodies

220. Which of the following statements regarding a double helical molecule of DNA is true? (AIIMS 2001)
(a) Each strand is identical
(b) Each strand replicates itself

(c) Bases are perpendicular to the axis
(d) All hydroxyl groups are involved in linkage

*221. Teminism is the same as: (AIIMS 1995)
(a) Translation (b) DNA synthesis
(c) Transcription (d) Reverse transcription

222. Transcription occurs in presence of: (CPMT 2001; MPPMT 2001)
(a) DNA polymerase I (b) DNA polymerase II
(c) RNA polymerase (d) DNA polymerase III

*223. In negative operon: (CBSE 2001)
(a) Co-repressor binds with repressor
(b) Co-repressor does not bind with repressor
(c) Co-repressor binds with inducer
(d) cAMP have negative effect on lac operon

224. What is true for plasmid? (CBSE 2001)
(a) Plasmids are widely used in gene transfer
(b) These are found in virus
(c) Plasmid contains gene for vital activities
(d) These are main part of chromosome

225. Which of the following cut the DNA from specific places? (CBSE 2001)
(a) Restriction endonuclease
(b) Ligase
(c) Exonuclease
(d) Alkaline phosphatase

226. *E. coli* about to replicate was placed in a medium containing radioactive thymidine for 5 minutes. Then it was made to replicate in a normal medium. Which of the following observations shall be correct? (CBSE 2001)
(a) Both the strands of DNA will be radioactive
(b) One strand is radioactive
(c) Each strand is half radioactive
(d) None is radioactive

*227. Types of RNA polymerase required in nucleus for RNA synthesis in eukaryotes: (CBSE 2001)
(a) 1 (b) 2
(c) 3 (d) 4

228. Gene and cistron words are sometimes used synonymously because: (CBSE 2001)
(a) One cistron contains many genes
(b) One gene contains many cistrons
(c) One gene contains one cistron
(d) One gene contains no cistron

229. m-RNA is synthesized in DNA template in which direction? (CBSE 2001)
(a) 5′ → 3′ (b) 3′ → 5′
(c) Both (a) and (b) (d) None of these

230. Base sequence of DNA is ATGCTTAG. What will be the sequence of m-RNA? (Uttaranchal PMT 2001)
(a) TACGAATC (b) TUCGUUAC
(c) CATAGCAT (d) UAGGUUTC

*231. Part of a gene which codes for an enzyme is: (Manipal 2001)
(a) Cistron (b) Exon
(c) Intron (d) Codon

232. Which of the following codons performs same function as UAG and UGA? (Manipal 2001)
(a) GUG (b) AUG
(c) UAA (d) UGG

233. This is not produced by *E. coli* in the lactose medium: (CET Karnataka 2001)
(a) Thiogalactoside transacetylase
(b) Lactose dehydrogenase
(c) Lactose permease
(d) β-galactosidase

234. Which one of the following is not a component of lac operon model? (CET Karnataka 2001)
(a) Structural gene (b) Promoter gene
(c) Regulator gene (d) Primer gene

235. Plasmids occur in: (CET Karnataka 2001)
(a) Chromosomes (b) Viruses
(c) Chloroplasts (d) Bacteria

236. Thermal cycler is used in this reaction: (CET Karnataka 2001)
(a) Enzyme catalyzed reactions
(b) Radioactivity
(c) Polymerase chain reaction
(d) Chemical reactions

237. Who got the Nobel Prize for discovery and use of restriction enzymes in genetic engineering?
(a) Paul Berg (b) Arber, Nathan and Smith
(c) K. Mullis (d) F. Sanger

238. Principle of synthesis of recombinant DNA molecules lies in:
(a) Blunt ends of DNA pieces
(b) Sticky ends of DNA pieces
(c) Both (a) and (b)
(d) None of the above

239. Restriction enzymes occur in:
(a) Algae (b) Fungi
(c) Bacteria (d) Viruses

240. A technique used to amplify a specific DNA fragment of interest is:
(a) Blotting technique (b) PCR
(c) DNA finger printing (d) Gel electrophoresis

241. In polymerase chain reaction, DNA polymerase enzyme used is:
(a) DNA polymerase I (b) DNA polymerase II
(c) Taq polymerase (d) DNA polymerase III

242. The best known cloning vector among higher plants is:
(a) Bacteriophage
(b) Ti plasmid of *Agrobacterium*
(c) Cosmid
(d) Plant virus

243. A mutant micro-organism unable to synthesize a compound required for its growth but able to grow if the compound is provided, is known as: (MPPMT 2001)
(a) Auxotroph (b) Prototroph
(c) Autotroph (d) None of these

244. Translation is the process in which: (MPPMT 2001)
(a) DNA is formed on DNA template
(b) RNA is formed on DNA template
(c) DNA is formed on RNA template
(d) Protein is formed on RNA message

245. Major latest area of research in biology is:
(a) Tissue culture
(b) Genomics
(c) Recombinant DNA technology
(d) None of the above

246. Complete genome of which non-crop plant has already been sequenced?
(a) *Datura* (b) *Arabidopsis*
(c) *Oenothera* (d) None of these

247. Genomics studies represent:
(a) Classical genetics (b) Reverse genetics
(c) Both (a) and (b) (d) None of these

248. Complete genome of which crop plant is being sequenced and is likely to become available in the year 2003?
(a) Maize (b) Wheat
(c) Oat (d) Rice

249. The newer tool that made genomics research possible in recent years is:
(a) DNA chips (b) Mass spectrometry
(c) Automatic sequencers (d) All of these

250. Some progress has been made in which class of genomics research?
(a) Structural genomics (b) Functional genomics
(c) Application genomics (d) None of these

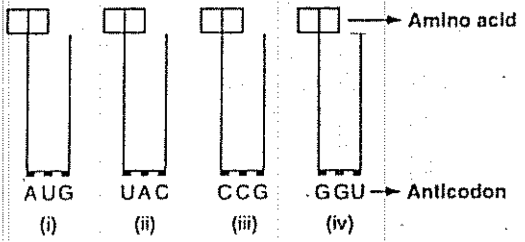
251. DNA is a genetic material was proved by: **[BCECE (P.T. Exam.) 2001]**
(a) Griffith (b) Linus Pauling
(c) Meselson and Stahl (d) Watson

252. Jumping genes are referred to as: **[BCECE (P.T. Exam.) 2001]**
(a) Exons (b) Introns
(c) Cytoplasmic particles (d) Transposons

253. Construction of a recombinant DNA involves: **(CET Karnataka 2002)**
(a) Cleaving DNA segments with 'Endonuclease' and rejoining them with 'Ligase'
(b) Cleaving and rejoining DNA segments with 'Endonuclease' alone
(c) Cleaving and rejoining DNA segments with 'Ligase' alone
(d) Cleaving DNA segments with 'Ligase' and rejoining them with 'Endonuclease'

254. Chargaff's rule is applicable to: **(CET Karnataka 2002)**
(a) Single stranded DNA and RNA
(b) Single stranded RNA
(c) Double stranded DNA
(d) Single stranded DNA

*255. Find the sequence of binding of the following amino acyl t-RNA complexes during translation to a m-RNA transcribed by a DNA segment having the base sequence 3' TACATGGGT CCG 5'. Choose the answer showing the correct order of numerals: **(CET Karnataka 2002)**



(a) ii, i, iv, iii (b) i, ii, iv, iii
(c) ii, i, iii, iv (d) i, ii, iii, iv

256. A nucleoside differs from nucleotide in not having the: **(CET J & K 2002)**
(a) Sugar (b) Nitrogen base
(c) Glucose (d) Phosphate group

257. Nucleic acid can be fragmented by the enzyme: **(CET J & K 2002)**
(a) Polymerases (b) Nucleases
(c) Proteases (d) Ligases

258. Wobble hypothesis was given by: **(AIIMS 2002)**
(a) R.W. Holley (b) H.G. Khorana
(c) M. Nirenberg (d) F.H.C. Crick

259. Out of 64 codons, 61 codons code for 20 types of aminoacids; it is called: **(CBSE 2002)**
(a) Degeneracy of genetic code
(b) Overlapping of gene
(c) Wobbling of codon
(d) Universality of codon

260. Jacob and Monod studied lactose metabolism in *E.coli* and proposed operon concept, which is applicable to: **(CBSE 2002)**
(a) All prokaryotes
(b) All prokaryotes and some eukaryotes
(c) All prokaryotes and all eukaryotes
(d) All prokaryotes and some protozoans

261. In *E.coli*, during lactose metabolism repressor binds to: **(CBSE 2002)**
(a) Regulator gene (b) Operator gene
(c) Structural gene (d) Promotor gene

262. Manipulation of DNA in genetic engineering became possible due to the discovery of: **(CBSE 2002)**
(a) Restriction endonuclease (b) DNA ligase
(c) Transcriptase (d) Primase

263. Exons are the expressible part of DNA. They express to form: **(CBSE 2002)**
(a) Sugars (b) Lipid
(c) Protein (d) Fatty acid

264. If a type of bacteria can grow on minimal medium containing streptomycin, what can be the probable reason for this action? **(CBSE 2002)**
(a) A gene was already present in bacteria which detoxify the action of streptomycin
(b) On growing in the medium the bacteria acquire the resistance against streptomycin
(c) They secrete enzymes against streptomycin
(d) Bacteria have cell wall so streptomycin cannot work against it

265. The anticodon of t-RNA binds with: **(VVMC-Safdarjung 2001)**
(a) Nucleic bases of m-RNA
(b) Nucleic bases of r-RNA
(c) Codons of t-RNA
(d) Amino acid

266. According to latest findings, human genome has genes: **(DPMT 2001)**
(a) 100,000 (b) 200,000
(c) 20,000 (d) 30,000

267. Nobel Prize for concept of jumping genes was awarded to: **(MPPMT 2002)**
(a) H.G. Khorana (b) Barbara McClintock
(c) Kornberg (d) Watson

*268. Identify the vector suitable to clone long fragments of DNA: **(EAMCET 2002)**
(a) Phage vectors (b) Bacterial plasmids
(c) Yeast plasmids (d) Cosmids

269. Which RNA is present in least amount in a cell? **(CET MH 2003)**
(a) m-RNA (b) t-RNA
(c) r-RNA (d) All are in equal quantity

270. Which of the following has clover leaf shape? **(Jharkhand CECE 2003)**
(a) m-RNA (b) t-RNA
(c) r-RNA (d) Sn-RNA

271. Which of the following is associated with nucleolus? **(Jharkhand CECE 2003)**
(a) t-RNA (b) r-RNA
(c) m-RNA (d) DNA

*272. Which one of the following can give a complimentary and palindromic sequence? **(EAMCET 2003)**
(a) 5′ ATATCC 3′ (b) 5′ CCGAAT 3′
(c) 5′ GAATTC 3′ (d) 5′ AGGTTC 3′

273. Transcription requires: **(AMU 2003)**
(a) RNA polymerase (b) DNA polymerase
(c) DNA ligase (d) Topoisomerase

274. An extrachromosomal DNA which can be used as vector in gene cloning is called: **(CET J&K 2003)**
(a) Transposon (b) Intron
(c) Exon (d) Plasmid

275. Which of the following enzymes is used in DNA multiplication (replication)? **(CPMT 2003)**
(a) RNA polymerase (b) DNA endonuclease
(c) Exonuclease (d) DNA polymerase

276. DNA and RNA differ by: **(BHU 2003)**
(a) N-bases and phosphate groups
(b) Number of C-atoms in sugars
(c) N-bases and sugars
(d) Sugar and phosphate groups

277. A bacteriophage with radioactive DNA and protein when infects a bacterium the radioactivity inside the bacterium will be located: **(Orissa JEE 2003)**
(a) In DNA
(b) In protein
(c) Both in DNA and protein
(d) In all parts of bacterial cell

278. Restriction endonucleases cut: **(Orissa JEE 2003)**
(a) Double stranded DNA (b) Single stranded DNA
(c) Single stranded RNA (d) Double stranded RNA

279. Which of the following is not correct? **(DPMT 2003)**
(a) A/T = 1 (b) A + T = G + C
(c) A + G = C + T (d) C/A = 1

280. The specific DNA sequence where EcoRI cuts is: **(Kerala PMT 2003)**
(a) GATTCG
TAAGCT
(b) GAATTC
CTTAAG
(c) GTTCAA
CAAGTT
(d) TTCGAA
AAGCTT

281. The four nitrogen base sequences which form the code words for DNA language are: **(Kerala PMT 2003)**
(a) UTAC (b) ACTU
(c) AGGU (d) ATCG

282. What does 'lac' refer to in what we call the lac operon? **(CBSE 2003)**
(a) Lactase (b) Lactose
(c) Lac insect (d) The number 1,00,000

283. Degeneration of a genetic code is attributed to the: **(CBSE 2003)**
(a) Entire codon
(b) First member of codon
(c) Second member of codon
(d) Third member of a codon

284. Which one of the following pairs of terms/names mean one and the same thing? **(AIIMS 2003)**
(a) Gene pool—genome
(b) Codon—gene
(c) Cistron—triplet
(d) DNA fingerprinting—DNA profiling

285. The modern concept of gene is: **(UGET-Manipal 2003)**
(a) A segment of chromosome
(b) A segment of DNA
(c) A functional unit of DNA
(d) A segment of DNA capable of crossing over

286. If during the initiation of meiosis there is 16 pg of DNA in a gametocyte. Then the amount of DNA present in the gamete will be: **(MGIMS Wardha 2003)**
(a) 8 pg (b) 16 pg
(c) 4 pg (d) 32 pg

ANSWERS

1—c	2—a	3—a	4—c	5—c	6—c	7—d	8—b	9—b	10—d	11—c	12—c
13—c	14—b	15—b	16—a	17—d	18—d	19—a	20—b	21—c	22—a	23—b	24—b
25—b	26—a	27—c	28—b	29—a	30—c	31—d	32—d	33—c	34—d	35—c	36—c
37—b	38—d	39—a	40—b	41—c	42—b	43—a	44—d	45—b	46—a	47—b	48—d
49—a	50—d	51—b	52—c	53—a	54—d	55—c	56—c	57—c	58—c	59—c	60—a
61—c	62—c	63—b	64—b	65—d	66—c	67—a	68—c	69—c	70—a	71—a	72—c
73—b	74—b	75—c	76—c	77—b	78—b	79—b	80—d	81—c	82—a	83—b	84—d
85—b	86—d	87—b	88—b	89—c	90—c	91—c	92—c	93—b	94—d	95—c	96—a
97—c	98—b	99—c	100—c	101—b	102—d	103—a	104—c	105—d	106—c	107—c	108—c
109—a	110—d	111—a	112—b	113—a	114—d	115—a	116—d	117—b	118—a	119—d	120—b
121—a	122—b	123—a	124—d	125—d	126—c	127—b	128—a	129—d	130—a	131—b	132—d
133—b	134—b	135—b	136—a	137—b	138—a	139—c	140—b	141—d	142—a	143—c	144—b
145—a	146—a	147—c	148—d	149—a	150—d	151—c	152—d	153—c	154—b	155—c	156—a
157—c	158—c	159—b	160—b	161—a	162—c	163—a	164—b	165—a	166—a	167—c	168—d
169—c	170—c	171—d	172—b	173—c	174—d	175—a	176—a	177—d	178—c	179—b	180—c
181—b	182—d	183—b	184—b	185—a	186—a	187—b	188—b	189—b	190—a	191—d	192—b
193—c	194—d	195—d	196—d	197—d	198—c	199—c	200—b	201—a	202—b	203—a	204—a
205—c	206—c	207—d	208—c	209—d	210—a	211—b	212—d	213—d	214—a	215—d	216—b
217—b	218—b	219—b	220—c	221—d	222—c	223—a	224—a	225—a	226—b	227—c	228—c
229—a	230—a	231—a	232—c	233—b	234—d	235—d	236—c	237—b	238—b	239—c	240—b
241—c	242—b	243—a	244—d	245—b	246—b	247—b	248—d	249—d	250—a	251—a	252—d
253—a	254—c	255—a	256—d	257—b	258—d	259—a	260—a	261—b	262—a	263—c	264—a
265—a	266—d	267—b	268—d	269—a	270—b	271—b	272—c	273—a	274—d	275—d	276—c
277—a	278—a	279—c	280—b	281—d	282—b	283—d	284—d	285—c	286—a		

EXPLANATION OF SELECTED QUESTIONS (*)

45. Adenine is 6-amino purine, hence its base analogue is 2-amino purine.
49. Hershey and Chase by his Wareing blender experiment confirmed that DNA of bacteriophage enters into the host cell and carries the necessary information for formation of new phages.
64. Reverse transcription was first shown in *Rous sarcoma* virus.
74. Genetic code is triplet, *i.e.*, sequence of three N-bases or nucleotides codes an amino acid.
96. *Anabaena* and *E. coli* are prokaryotes, which have only DNA (*i.e.*, not combined with histone proteins).
98. Heterochromatins have little or no transcriptional activity (as observed by autoradiography).
101. Number of adenine is equal to thymine and that of guanine is equal to cytosine, hence total number of nucleotides is sum of all the four bases.
110. Three are nonsense codons.
128. H-bonds occur between N-bases of nucleotides of two polynucleotide chains of DNA. N-bases are attached to C-1 of sugar of nucleotides. Hence these bonds can be formed in antiparallel chains only.
178. Peptide bond formation between amino acids at P-site and A-site of ribosome is catalysed by peptidyl transferase enzyme and it does not require energy.
180. In prokaryotes, the first amino acid methionine is formylated which is carried by t-RNA$_f$ *met*.
184. UGA in yeast mitochondria codes tryptophan amino acid while in all other cases, it is a nonsense codon.
189. Operator is often called on/off switch of transcription and hence functioning of structural genes is controlled by operator.
192. DNA replication (in S-phase) can occur only in diffused or dispersed euchromatin and not in condensed compacted heterochromatin.
194. Prokaryotes have DNA and are altogether lacking in histones.
195. A particular length of DNA is called gene.
213. Dulbecco along with Temin and Baltimore discovered reverse transcription in *Rous sarcoma* virus (associated with cancer).
216. Phosphodiester bonds are covalent bonds.
221. Reverse transcription was discovered by Temin (hence called Teminism).
223. In tryptophan operon (negative control) tryptophan or co-repressor binds with inactive repressor to make it active.
227. Three types of RNA polymerases occur in eukaryotes (one in prokaryotes).
231. Functional unit of gene is cistron.
255. Anticodons of t-RNA have complementary base sequence to those of m-RNA codons.
268. Cosmids are the plasmids that contain lambda phage 'cos' sites and these are used to clone long segments of DNA.
272. A sequence in which the partner strand read in $5' \rightarrow 3'$ direction is identical in sequence, is called palindromic sequence.

8

Genetics

- ☐ Introduction and historical background
- ☐ Mendelism or Mendel's laws of inheritance
- ☐ Back cross
- ☐ Test cross
- ☐ Modification of F_2 ratios or Interaction of factors—Incomplete dominance, lethal factors, complementary factors, supplementary factors, epistatic factors, inhibitory factors, duplicate factors and polymeric factors
- ☐ Some other patterns of inheritance-Multiple allelism, pleiotropy
- ☐ Linkage
- ☐ Crossing over
- ☐ Structural changes in chromosomes
- ☐ Numerical changes in chromosomes
- ☐ Mutations
- ☐ Cytoplasmic or Extranuclear Inheritance
- ☐ Sex linked traits and their inheritance
- ☐ Sex-determination
- ☐ *Neurospora*–genetics

The branch genetics started in 1900 after rediscovery of Mendel's work.

- **Gregor Johann Mendel** is rightly called **father of genetics.**
- Term **Genetics** was first used by **W. Bateson** (1905).
- Genetics is the branch which deals with heredity and variations.
- Heredity includes the characters which are transmitted from generation to generation and these characters are fixed for a particular organism.
- Variations or differences are of two basic types:

(a) **Hereditary variations:** The differences or variations which are transmitted from one generation to another generation or these are transmitted from parents to their progeny. Further, these are due to **sexual reproduction.**

(b) **Environmental variations:** The differences or variations which are **not fixed,** but are **environmentally induced.**

- In organisms without sexual reproduction, hereditary variations are greatly absent. The basic concept of heredity is known for a long time, but the actual physical link was unknown.

Work of some earlier workers is given below in brief:

Swammerdam (1679): Gave concept of **'Homunculus'**, *i.e.,* an organism develops simply by enlargement of a **minute individual,** present in egg or sperm.

Wolff (1738–94): Gave **concept of epigenesis,** *i.e.,* each gamete is having undifferentiated living substance which gives rise to complete organism after fertilization.

Charles Darwin (1809–92): He gave the **concept of pangenes.** According to this concept, each organ of the body contains invisible and minute bodies called **pangenes** or **gemmules,** which are taken to sex organs and gametes with blood. After fertilization, zygote is formed in which pangenes or gemmules of all organs are collected and due to these pangenes, different body characters develop.

A. Weismann (1834–1914): Proposed his **germplasm theory** (theory of continuity of germplasm) which was a significant advancement in understanding of heredity. According to this theory there are two types of tissues in the body of an individual, *i.e.,* **germplasm** and **somatoplasm.** The variations present in somatoplasm are not transmitted to next generation as somatoplasm is unable to enter in sex-cells whereas variations present in germplasm are transmitted to progeny as germplasm is meant for reproductive purpose only. His theory was based upon experiments consisting of cutting the tails of mice for 22 generations.

Johannsen (1909): **Genotype-phenotype concept** was given by him.

- **Genotype** is the **sum total of heredity** or genetic constitution or genetic make up.
- **Phenotype** is the **external feature** of organism. Phenotype is due to g × e interaction, *i.e.,* genotype and environment interaction.
- **Phenocopies**—When two **different** genotypes due to different environmental conditions (environment) give rise to same phenotype, then one is said to be phenocopy of other.

MENDELISM OR MENDEL'S LAWS OF INHERITANCE

Gregor Johann Mendel (1822–1884), who is known as **father of genetics,** was a monk of **Austria** and he was a teacher in Augustinian Monastery at **Brunn** (in Czeckoslovakia, now called **Brno**).

- In 1857, Mendel started his experiments on common garden pea *(Pisum sativum)* and he worked for 8 years. In 1866, he published the results of his experiments in 'Annual Proceedings of Natural History Society of Brunn'.

- For about three decades (34 years), this work of Mendel remained hidden or buried and it was in 1900, three workers rediscovered Mendel's work independently. These were:
  - (a) **Hugo de Vries**—Belonged to Holland or Netherland and worked on evening primrose *(Oenothera)*.
  - (b) **Karl Correns**—Belonged to Germany and worked on maize *(Zea mays)*.
  - (c) **Tschermak**—Belonged to Austria and he worked on different flowering plants.

These three workers also reached the same conclusion and they republished the original work of Mendel in 'Flora' (1901).

Mendel's experimental material

Mendel selected common garden pea *(Pisum sativum)* for his experiments, because:

- (i) Pea is having a number of well defined differentiating characters or contrasting characters.
- (ii) Having hermaphrodite or bisexual flowers.
- (iii) Predominantly self-fertilization (autogamy).
- (iv) Hybridization or crossing is easy. For hybridization, **emasculation** is done, *i.e.*, removal of stamens (male part) from the flower.
- (v) Having short life span.

Netherland

- Mendel chose seven pairs of contrasting characters for his experiments and each pair was a unit.

S. No.	Pairs of contrasting characters	Dominant	Recessive
1.	Smooth *vs.* wrinkled seed form	Smooth	Wrinkled
2.	Yellow *vs.* green colour of cotyledons	Yellow	Green
3.	Coloured *vs.* white seed coat (testa)	Coloured	White
4.	Inflated *vs.* constricted pod type	Inflated	Constricted
5.	Green *vs.* yellow pod colour	Green	Yellow
6.	Axial *vs.* terminal position of flowers	Axial	Terminal
7.	Tall *vs.* dwarf plant height	Tall	Dwarf

- A pair of contrasting characters or differentiating characters is called as **determiners** or **traits** or **factors** or **genes** or **alleles** or **allelomorphs**.
- Term **allele** or **allelomorph** was given by **W. Bateson** for alternative forms of same gene, *e.g.*, T and t, Y and y, R and r, are pair of alleles.

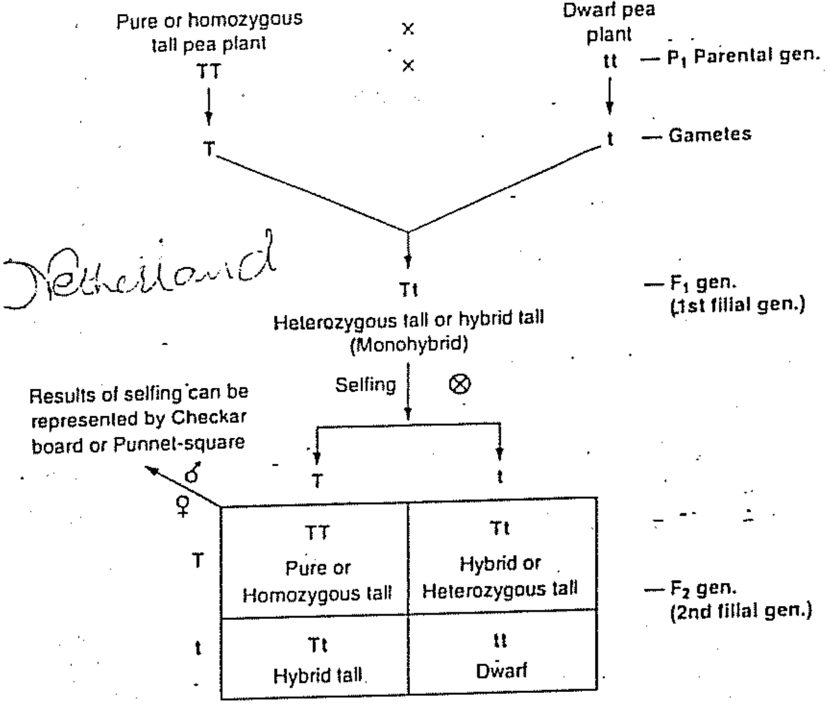
- o Genes controlling seven traits (characters) in pea studied by Mendel are now known to be located on only 4 chromosomes (out of 7), *i.e.*, of cotyledon and seed coat colour on chromosome 1; of pod form, flower position and stem length on chromosome 4; of pod colour on chromosome 5 and of seed form on chromosome 7.

Experiments of Mendel

Mendel performed two types of crosses:

1. Monohybrid crosses

When only a single pair of contrasting or differentiating characters is considered in a cross (or inheritance of only one pair of contrasting characters is studied in a cross), it is called monohybrid cross, *e.g.*,


Pure or homozygous tall pea plant
TT
×
Dwarf pea plant
tt
— P₁ Parental gen.
T
t
— Gametes
Tt
Heterozygous tall or hybrid tall (Monohybrid)
— F₁ gen. (1st filial gen.)
Selfing
⊗
Results of selfing can be represented by Checkar board or Punnet-square
♂
♀
T
t
T
t
TT Pure or Homozygous tall
Tt Hybrid or Heterozygous tall
Tt Hybrid tall
tt Dwarf
— F₂ gen. (2nd filial gen.)

- **Phenotypic ratio in F_2 gen. of monohybrid cross**
  = 3 (tall) : 1 (dwarf)
- **Genotypic ratio in F_2 gen. of monohybrid cross**
  = 1 (Pure tall) : 2 (Hybrid tall) : 1 (dwarf)
- **Homozygous or pure:** Organism having two similar genes or alleles for a particular character in a homologous pair of chromosomes, *e.g.*, TT or tt.
- **Heterozygous or hybrid:** Organism containing two different alleles or individual containing both dominant and recessive genes of an allelic pair, *e.g.*, Tt.

On the basis of monohybrid crosses, two laws have been given:

(a) Law of dominance: It states, "When a pair of alleles or allelomorphs are brought together in F_1 hybrid, then only one of them expresses itself, masking the expression of other completely."

e.g., In Tt-F_1 hybrid,
(tall)
only 'T' expresses itself—so **dominant**
and 't' is masked—so **recessive**

(b) Law of segregation or Law of purity of gametes: It states that, "When a pair of alleles or allelomorphs are brought together in F_1 hybrid, they remain together (coexist) without mixing or contaminating or blending with each other and separate complete and pure during formation of gametes (gametogenesis)."

- It is also known as **'Law of purity of gametes'** because each gamete is pure in itself, *i.e.*, having either T (*i.e.*, gene for tallness) or t (*i.e.*, gene for dwarfness).

II. Dihybrid crosses

When inheritance of two pairs of contrasting characters is studied simultaneously in a cross, it is called **dihybrid cross.**

Or

Such a cross in which two pairs of contrasting characters are taken into consideration simultaneously, is called **dihybrid cross,** *e.g.*, cross between pea variety having **yellow cotyledons and round (smooth) seeds** with another variety having **green cotyledons and wrinkled seeds.**

So in F_2 gen. of dihybrid cross:

Phenotypic ratio: 9 (yellow—round) : 3 (yellow—wrinkled) : 3 (green—round) : 1 (green—wrinkled)

Genotypic ratio: 1 : 2 : 2 : 4 : 1 : 2 : 1 : 2 : 1

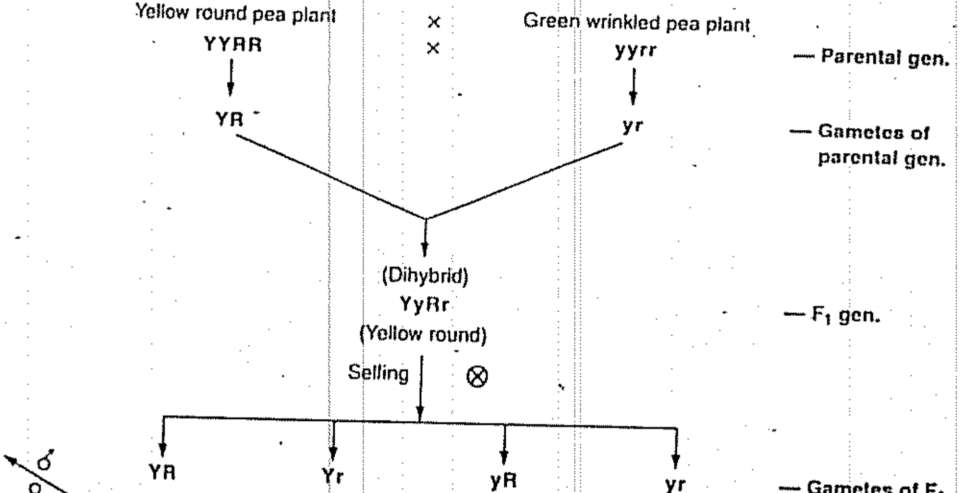
- (In F_2 gen. of dihybrid cross, the expected genotypic proportion of individuals having **both the dominant alleles in homozygous** condition is 1/16 and also genotypic proportion of individuals having **both recessive alleles in homozygous** condition is 1/16).

On the basis of dihybrid crosses, another law of inheritance has been given called **'Law of Independent assortment'.**

(c) Law of independent assortment: It states, "When two pairs of independent alleles are brought together in F_1 hybrid, they show **independent dominant effects,** in the formation of gametes law of segregation occurs and the factors (genes) assort themselves independently, at random and freely."

Importance of Mendelism

- On the basis of Mendelism, different breeds in animals (like horses, fowls, etc.) have been produced. Similarly, different varieties in plants have been produced.
- Science of **eugenics** (development of superior progeny) is also based on Mendelism.
- Further on the basis of Mendelism, **hybrid vigour or heterosis** has been utilized in different organisms (plants and animals).



♀ \ ♂	YR	Yr	yR	yr
YR	YYRR (Yellow round)	YYRr (Yellow round)	YyRR (Yellow round)	YyRr (Yellow round)
Yr	YYRr (Yellow round)	YYrr (Yellow wrinkled)	YyRr (Yellow round)	Yyrr (Yellow wrinkled)
yR	YyRR (Yellow round)	YyRr (Yellow round)	yyRR (Green round)	yyRr (Green round)
yr	YyRr (Yellow round)	Yyrr (Yellow wrinkled)	yyRr (Green round)	yyrr (Green wrinkled)

— F_2 gen.

- (The term heterosis for hybrid vigour was given by G.H. Shull).

Some problems

Problem 1. *What types of gametes are formed by the genotype RrYy?*

Solution: RrYy is a dihybrid from which four types of gametes namely RY, Ry, rY and ry will be formed.

Problem 2. *How many types of gametes can be formed from the following genotypes?*

(a) Dd (b) DDEE (c) AABbCc (d) AABBCc

Solution: (a) Dd is a monohybrid from which two types of gametes namely D and d are formed.

(b) DDEE is homozygous and only one type of gamete namely DE will be formed.

(c) AABbCc is dihybrid from which four types of gametes namely ABC, ABc, AbC and Abc are formed.

(d) AABBCc is a monohybrid from which only two types of gametes namely ABC and ABc are formed.

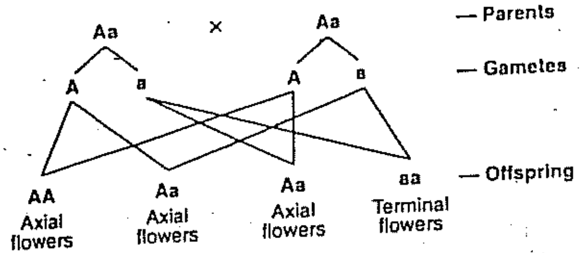
Problem 3. *What will be the genotypes of the parents (using symbols Dd and Ee) whose offspring has phenotypes in 9 : 3 : 3 : 1 proportion?*

Solution: 9 : 3 : 3 : 1 phenotypic ratio is obtained by selfing of F_1 dihybrid. Hence genotypes of the parents are:

DdEe and DdEe

Problem 4. *In garden pea, axial flowers (A) are dominant over terminal flowers (a). What will be the proportion of offspring with axial flowers in the cross Aa × Aa?*

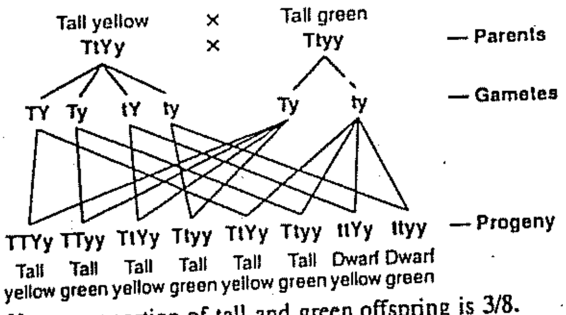
Solution: This is selfing of monohybrid.


Aa
×
Aa
— Parents
A
a
A
a
— Gametes
AA
Axial flowers
Aa
Axial flowers
Aa
Axial flowers
aa
Terminal flowers
— Offspring

Hence proportion of offspring with axial flowers is 3/4.

Problem 5. *What proportion of offsprings is expected to be tall and green in a cross between tall pea plant with yellow cotyledons (TtYy) and tall plant with green cotyledons (Ttyy)?*

Solution:

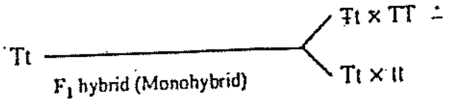

Tall yellow
TtYy
×
×
Tall green
Ttyy
— Parents
TY
Ty
tY
ty
Ty
ty
— Gametes
TTYy
TTyy
TtYy
Ttyy
TtYy
Ttyy
ttYy
ttyy
— Progeny
Tall
Tall
Tall
Tall
Tall
Tall
Dwarf
Dwarf
yellow
green
yellow
green
yellow
green
yellow
green

Hence proportion of tall and green offspring is 3/8.

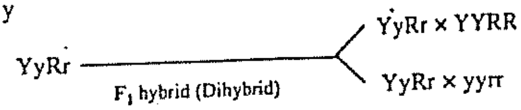
BACK CROSS

Crossing of F_1 hybrid with either of its parents is called back cross.

- In back cross, F_1 hybrid may be crossed with either homozygous dominant parent or with homozygous recessive parent. Thus there are two back crosses possible, *e.g.*,


Tt
Tt × TT
Tt × tt
F₁ hybrid (Monohybrid)

Similarly

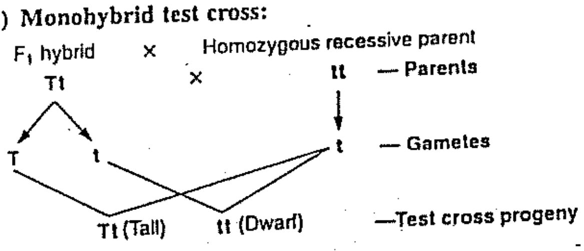

YyRr
YyRr × YYRR
YyRr × yyrr
F₁ hybrid (Dihybrid)

TEST CROSS

It is a type of back cross.

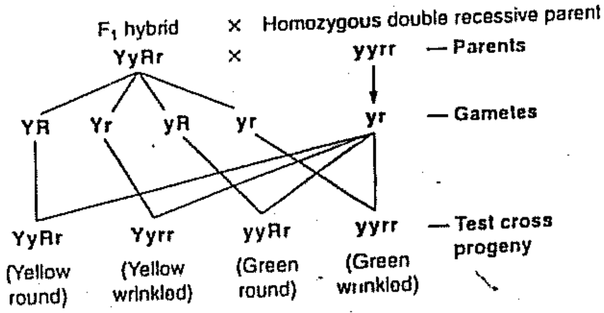
- **Crossing of F_1 individual having dominant phenotype with its homozygous recessive parent is called test cross and the progeny of test cross is called test cross progeny.** Test cross was devised by Mendel to prove that F_1 (obtained by crossing two pure breeding parents) is heterozygous or hybrid. Homozygous and heterozygous genotypes for dominant phenotype or trait cannot be distinguished as they show the same phenotype. By using test cross, genotype can be revealed. If the unknown genotype is homozygous, all progeny will exhibit the phenotype associated with dominant allele but if the unknown genotype is heterozygous, half the progeny will exhibit the dominant trait and half the recessive trait.

(a) Monohybrid test cross:


F₁ hybrid
×
Homozygous recessive parent
Tt
×
tt
— Parents
T
t
t
— Gametes
Tt (Tall)
tt (Dwarf)
—Test cross progeny

Thus monohybrid test cross ratio = $\boxed{1:1}$

(b) Dihybrid test cross:


F₁ hybrid
×
Homozygous double recessive parent
YyRr
×
yyrr
— Parents
YR
Yr
yR
yr
yr
— Gametes
YyRr
(Yellow round)
Yyrr
(Yellow wrinkled)
yyRr
(Green round)
yyrr
(Green wrinkled)
— Test cross progeny

- So dihybrid test cross ratio = $\boxed{1:1:1:1}$
- Similarly trihybrid test cross ratio = $\boxed{1:1:1:1:1:1:1:1}$
- Test cross is done for—
  - (i) To prove that 2 types of gametes are produced by monohybrid, 4 types of gametes are produced by dihybrid and 8 types of gametes are produced by trihybrid.
  - (ii) That these gametes are produced in equal number.
  - (iii) Genotype of the offspring can be tested by test-cross.

Some problems

Problem 1. *A tall pea plant was crossed with a dwarf plant and 2 types of offsprings, i.e., tall and dwarf are produced in the ratio of* 1 : 1. *What are the genotypes of the parent?*

Solution: As two types of offsprings are produced in the ratio of 1 : 1, so it is a **monohybrid test cross** and hence genotypes of parents are:

Tt and tt

Problem 2. *A yellow round pea plant was crossed with green wrinkled plant and 4 types of offsprings were produced in the ratio. of* 1 : 1 : 1 : 1. *What are the genotypes of parents?*

Solution: As four types of offsprings are produced in the ratio of 1 : 1 : 1 : 1 (dihybrid test cross ratio) so it is a **dihybrid test cross** and hence genotypes of parents are:

YyRr and yyrr

Problem 3. *A heterozygous yellow round pea plant was crossed with green wrinkled plant. How many types of offsprings will be produced and in what proportion?*

Solution: As it is a cross between a dihybrid and double recessive parent, so it is a **dihybrid test cross.** Hence 4 types of offsprings are produced in the ratio of 1 : 1 : 1 : 1.

MODIFICATION OF F_2 RATIOS OR INTERACTION OF FACTORS

(*i.e.*, modification of 3 : 1 ratio in monohybrid cross and 9 : 3 : 3 : 1 in dihybrid cross).

Mendel considered **1 : 1 relationship** between character and factor or gene, *i.e.*, **a single character is controlled by a single gene or factor.** But later on, it was observed that this 1 : 1 relationship is not always necessary and there may be cases **where more than one factors or genes control a single character.** Further, one factor or gene may be involved in more than one characters (*i.e.*, pleiotropic gene).

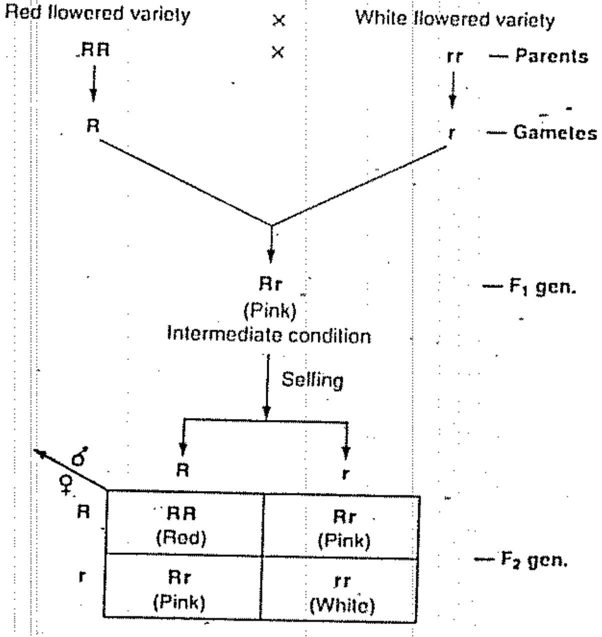
This hypothesis that 'a single character may be controlled by more than one factors (genes) and a single factor (gene) may affect more than one character' was first put forward by **W. Bateson** and is called **Bateson factor hypothesis or Bateson factor interaction.** These interactions modify normal F_2 ratios, *i.e.*, 3 : 1 in monohybrid crosses and 9 : 3 : 3 : 1 in dihybrid crosses.

(A) In monohybrid crosses

1. Blending Inheritance or Incomplete dominance (1 : 2 : 1)

Sometimes two genes of allelomorphic pair do not show dominant-recessive relationship, but when present simultaneously (or come together), they show **intermediate condition** or blend together, which is called **blending inheritance** or **incomplete dominance.**

- First case of incomplete dominance or blending inheritance was reported in *Mirabilis jalapa* **(4 o'clock plant) by Carl Correns** (1903). He reported that when a red or crimson flowered variety in this plant was crossed with white flowered variety, **pink flowers** (intermediate) are produced in F_1 gen. Selfing of F_1 hybrid results in three types of offsprings in F_2 gen., *i.e.*, **red, pink and white** in the ratio of **1 : 2 : 1.**
- Thus in F_2 of this cross, **same genotypic and phenotypic ratios** (*i.e.*, 1 : 2 : 1) are observed.



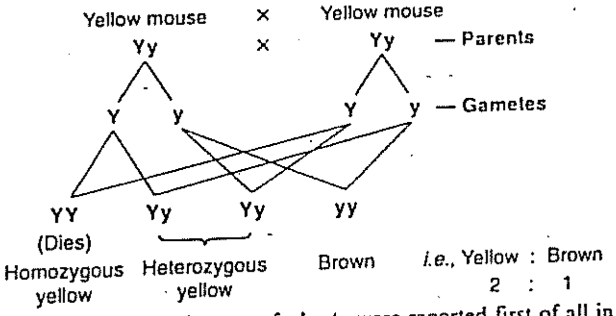
- So **genotypic and phenotypic ratios in F_2 gen.** = $\boxed{1:2:1}$
- **Snapdragons** (*Antirrhinum majus*) also provide an example of **incomplete dominance** or **blending-inheritance.**
- Incomplete dominance does not show true blending inheritance as selfing of F_1 individuals with pink flowers also produce individuals with parental red and white flowers in F_2 generation, which are not possible in case of true blending.
- **Co-dominance:** When the two genes neither show dominant-recessive relationship nor show intermediate condition, but **both of them express themselves simultaneously,** this condition is called **co-dominance.** This has been reported in **roan character of cattle** (*i.e.*, patches of 2 different colours on the skin).

2. Lethal factors

All the genes present in an organism are not useful, but some of them show harmful effects and sometimes may cause death or lethality. Such factors or genes which cause **death or lethality** in an organism are called **lethal factors** or genes.

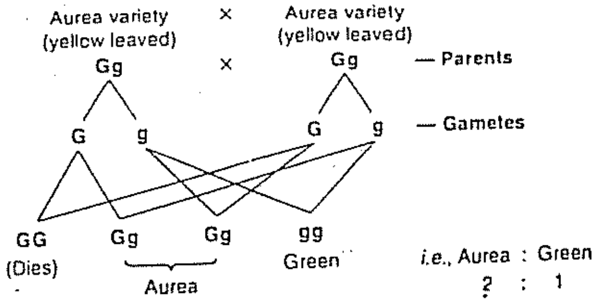
- These lethal factors are fortunately present in recessive state and thus cause death only in homozygous condition. In heterozygous condition, they may cause structural changes.

- Lethal factors were first of all reported in mice body colour by a French geneticist, **L.Cuenot** (1905). According to him, yellow mice never show true breeding and when yellow mouse is crossed with another yellow mouse, produce yellow and brown in the ratio of 2 : 1 (not 3 : 1). Yellow mouse is **never present in homozygous condition.**
- In the following example, 'Y' is a dominant gene for body colour but is **recessive for lethality** and when recessive genes come in homozygous condition, death is caused (*i.e.*, YY—dies).


Yellow mouse × Yellow mouse
Yy × Yy — Parents
Y y Y y — Gametes
YY Yy Yy yy
(Dies)
Homozygous yellow
Heterozygous yellow
Brown
i.e., Yellow : Brown
2 : 1

- Lethal factors in case of plants were reported first of all in **Snapdragons** ***(Antirrhinum majus)*** by **E. Baur** (1907).

Here also yellow leaved (golden leaved) or 'aurea' variety never breeds true. When aurea variety is crossed with aurea, aurea and green are produced in the ratio of 2 : 1 (not 3 : 1). *i.e.*, aurea is always heterozygous (Gg).


Aurea variety (yellow leaved) × Aurea variety (yellow leaved)
Gg × Gg — Parents
G g G g — Gametes
GG Gg Gg gg
(Dies)
Aurea
Green
i.e., Aurea : Green
2 : 1

Here again 'G' is dominant gene for yellow colour but is simultaneously recessive for lethality and when recessive genes come in homozygous condition, death is caused (*i.e.*, GG—dies).

Thus lethal factors cause modification of 3 : 1 ratio into 2 : 1.

(B) In dihybrid crosses

- Two gene pairs controlling the same character were first of all reported by **W. Bateson and Punnett** in fowl.

There are 4 types of combs present in fowl, *i.e.*, **pea type, rose type, walnut type and single type,** which are produced by two allelomorphic pairs of genes. Genotypes of different types are:

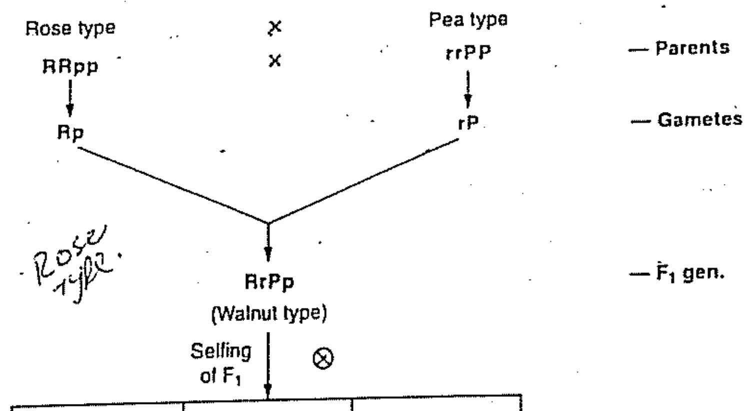
Rose type—RRpp
Pea type—rrPP
Walnut type—RrPp
Single comb—rrpp

- When a cross was made between rose type and pea type, a new combination called **walnut type** is produced in F_1 gen. (RrPp). This F_1 on selfing produced 9 walnut type, 3 pea type, 3 rose type and 1 single type in F_2 gen.

type
Rose

Dihybrid cross

Rose type.


Rose type × Pea type
RRpp × rrPP — Parents
Rp rP — Gametes
RrPp (Walnut type) — F₁ gen.
Selfing of F₁ ⊗

♂ / ♀	RP	Rp	rP	rp
RP	RRPP (Walnut)	RRPp (Walnut)	RrPP (Walnut)	RrPp (Walnut)
Rp	RRPp (Walnut)	RRpp (Rose)	RrPp (Walnut)	Rrpp (Rose)
rP	RrPP (Walnut)	RrPp (Walnut)	rrPP (Pea)	rrPp (Pea)
rp	RrPp (Walnut)	Rrpp (Rose)	rrPp (Pea)	rrpp (Single type)

— F_2 gen.

فوٹو کاپی

It has been seen in this case that:

- When dominant gene 'R' is present—Rose type comb is produced.
- When dominant gene 'P' is present—Pea type comb is produced.
- When both dominant 'R' and 'P' present—**Walnut type** comb is produced.
- When no dominant is present—Single type comb is produced.

So in F_2 gen.—9 (Walnut) : 3 (Pea) : 3 (Rose) : 1 (Single comb).

Hence from this above example, it is clear that **two gene pairs are affecting the same character.**

- **Some important interactions of factors and their modified F_2 ratios** are as follows:

1.	Interaction of complementary factors	9 : 7
2.	Interaction of supplementary factors	9 : 3 : 4
3.	Interaction of epistatic factors	12 : 3 : 1
4.	Interaction of inhibitory factors	13 : 3
5.	Interaction of duplicate factors	15 : 1
6.	Interaction of polymeric factors	9 : 6 : 1

1. Interaction of complementary factors (9 : 7)

Bateson observed two varieties in *Lathyrus odoratus* (Sweet pea), which are **true breeding** for white flowers (*i.e.*, on selfing give all white flowers). But it was observed that if these two white flowered varieties are crossed together, all progeny with red (purple) flowers were produced in F_1 gen. This F_1 on selfing gives **purple and white** in the ratio of 9 : 7 in F_2 gen., *i.e.*,

White variety × White variety
↓
Red (Purple) — F_1 gen.
Selfing ↓ ⊗
9 (Purple) : 7 (White) — F_2 gen.

- Bateson reported that **colour of flower** here is governed by 2 factors (genes):
  - (a) **Chromogen** (colourless): which forms basis of colour, controlled by a factor 'A'.
  - (b) **Activator:** which is capable of producing colour in presence of chromogen, controlled by factor 'B'.
- (In the two white flowered varieties observed by Bateson, one is having only **chromogen** (without activator) and another is having **only activator** (without chromogen).

So here **'A' and 'B'** factors are **complementary** to each other. When both these complementary factors come together, they produce **colour** (purple) and either of them **alone produce white flowers.** Such interaction of complementary factors modifies normal 9 : 3 : 3 : 1 F_2 ratio into 9 : 7.

White flowered variety × White flowered variety
AAbb × aaBB — Parents
↓ ↓
Ab aB — Gametes
↓
AaBb — F_1 gen.
(Purple flowered)
Selfing ↓ ⊗

♀ \ ♂	AB	Ab	aB	ab
AB	AABB (Purple)	AABb (Purple)	AaBB (Purple)	AaBb (Purple)
Ab	AABb (Purple)	AAbb (White)	AaBb (Purple)	Aabb (White)
aB	AaBB (Purple)	AaBb (Purple)	aaBB (White)	aaBb (White)
ab	AaBb (Purple)	Aabb (White)	aaBb (White)	aabb (White)

— F_2 gen.
Purple : White
9 : 7

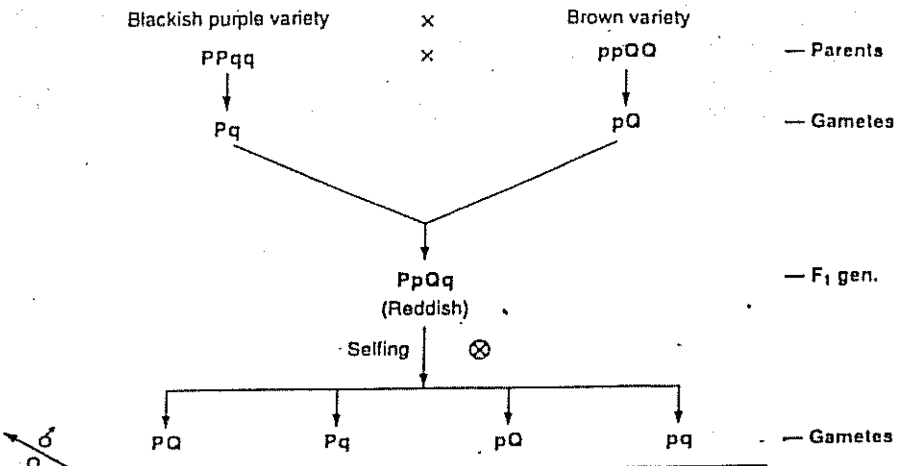
2. Interaction of supplementary factors (9 : 3 : 4)

Here as against complementary factors, one factor alone has its effect (*i.e.*, produces visible result) but the effect (visible result) is changed if supplemented with other factor, coming from other parent, *e.g.*, in *Sorghum*—blackish purple colour of grains is dominant over brown (*i.e.*, P/p) but this blackish purple colour is changed to **reddish if supplemented** with factor Q from other parent (**Q-modification factor**, has its no own effect but modifies the colour produced by 'P') (see adjoining figure).

So in F_2, ratio = 9 (reddish) : 3 (blackish purple): 4 (brown)

Here 'P' and 'Q' are **supplementary** to each other and their interactions lead to modification of normal F_2 ratio to 9 : 3 : 4.

- Interaction of supplementary factors also occurs in flower colour of snapdragons *(Antirrhinum majus)*.



♂ / ♀	PQ	Pq	pQ	pq
PQ	PPQQ (Reddish)	PPQq (Reddish)	PpQQ (Reddish)	PpQq (Reddish)
Pq	PPQq (Reddish)	PPqq (Blackish purple)	PpQq (Reddish)	Ppqq (Blackish purple)
pQ	PpQQ (Reddish)	PpQq (Reddish)	ppQQ (Brown)	ppQq (Brown)
pq	PpQq (Reddish)	Ppqq (Blackish purple)	ppQq (Brown)	ppqq (Brown)

— F_2 gen.

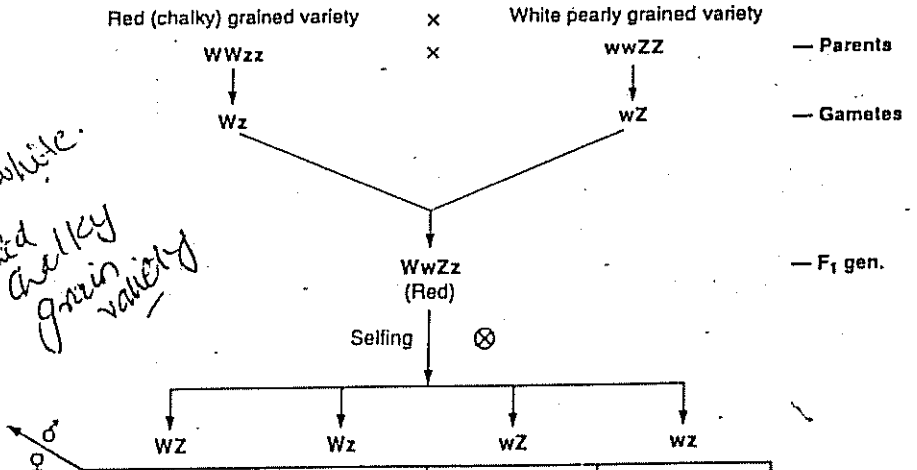
3. Interaction of epistatic factors (12 : 3 : 1)

The interaction of epistatic factors has been reported in **chloam**. The grains of chloam may be **red (W)**, or **white (w)** in colour and red is dominant over white, *i.e.*, W/w. Further the appearance of grains may be **pearly** (Z) or **chalky** (z) and pearly is dominant over chalky (Z/z). The **pearly grains** are shining, translucent and with high oil content, whereas **chalky grains** are opaque, dull and with low oil content.

white.

Red chalky grain variety

- A cross was made (see adjoining figure).
- In F_2 gen. = 12 (Red) : 3 (White pearly) : 1 (White chalky).
- Out of 12 **red progeny** of F_2 generation, 9 are actually red pearly and 3 are **red chalky**, but here red **colour masks the appearance of grains and hence no differentiation** can be made between red pearly and red chalky.
- Thus here **two independent factors (genes)** are affecting the character of grains, but W (red colour) is masking Z (appearance of grains), *i.e.*, 'W' suppresses 'Z' or **interallelic gene suppression,**



♂ / ♀	WZ	Wz	wZ	wz
WZ	WWZZ (Red)	WWZz (Red)	WwZZ (Red)	WwZz (Red)
Wz	WWZz (Red)	WWzz (Red)	WwZz (Red)	Wwzz (Red)
wZ	WwZZ (Red)	WwZz (Red)	wwZZ (White pearly)	wwZz (White pearly)
wz	WwZz (Red)	Wwzz (Red)	wwZz (White pearly)	wwzz (White chalky)

— F_2 gen.

which is called epistasis (Intrallelic gene suppression is called dominance).

- In epistasis, two factors or genes involved are **not allelomorphic**, whereas, in dominance, two factors relate to allelomorphic pair.
- In the given example, out of two independent factors, one expresses itself (Epistatic) and other is masked (Hypostatic).
- Such interactions give modified F_2 ratio as 12 : 3 : 1.

4. Interaction of inhibitory factors (13 : 3)

In this case, there is also involvement of two pairs of factors and **out of them one dominant inhibits the effect of other (second) dominant.**

- Inhibitory factors interaction has been reported in **pigmentation of rice plants.**
- Here **purple pigmented leaves (P) are dominant over green pigmented leaves** (p). When a cross was made between **purple pigmented and green pigmented varieties**, in F_1, all the plants were **green pigmented** and in F_2 generation, 13 **green** and 3 **purple** pigmented plants were produced.

So in F_2 gen. = 13 (green) : 3 (purple).

Thus here we see that I (inhibitory factor) is having no effect, but it inhibits the colour production by 'P' and in presence of inhibitory factor 'I', P does not produce purple pigmentation but green colour is produced. Interaction of such factors leads to modified F_2 ratio as **13 : 3**.

5. Interaction of duplicate factors (15 : 1)

When two pairs of factors are involved and both of them are able to produce the same effect singly as well as **in combination**, these are called **duplicate factors.**

- Example of duplicate factors occurs in **wheat**, where two types of varieties occur in relation to awns, *i.e.*, **awned** (with awns) and **awnless. Awned** character is controlled by duplicate factors, *i.e.*, A_1 and A_2.
- A cross made between awned and awnless varieties gives **awned progeny in F_1** and selfing of F_1 gives **15 awned and 1 awnless** in F_2 generation, *e.g.*, So here plants having A_1 or A_2 or both A_1 and A_2 are with awns (awned), *i.e.*, 15 and plant without A_1 and A_2 are without awns (awnless), *i.e.*, 1.

  [See figure on next Page (top).]

  So A_1 and A_2 are **duplicate factors.**
- G.H. **Shull** also reported interaction of duplicate factors in *Capsella bursa-pastoris* (Shepherd's purse).

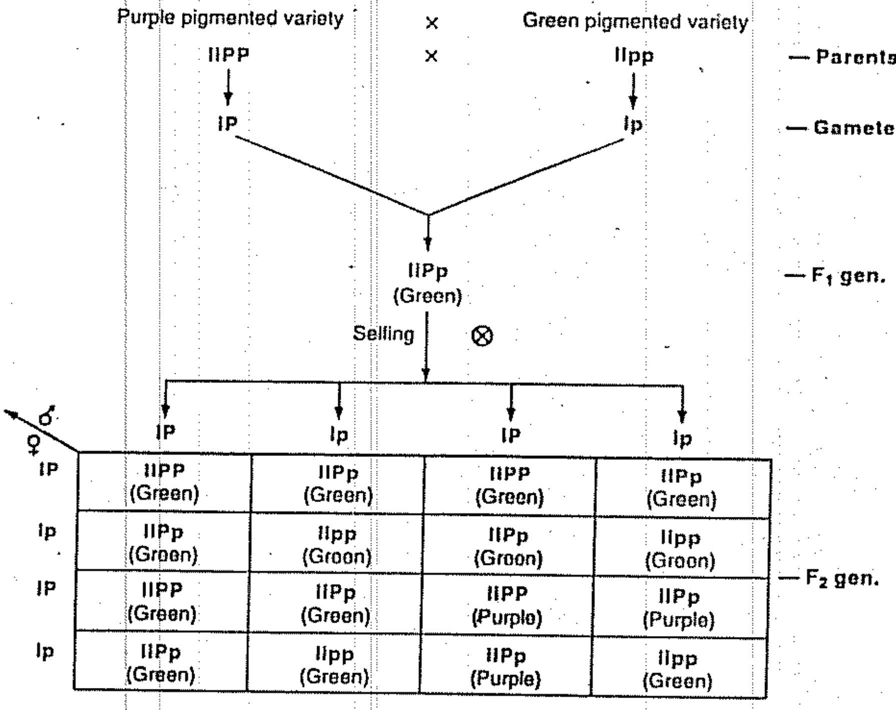
6. Interaction of polymeric factors (9 : 6 : 1)

When **number of genes or factors** affect or control the same character, their mode of action is **purely quantitative,** *i.e.*, **addition or substraction** from the total effect (more genes more effect, less genes less effect). Such types of factors are called **polymeric factors.**

- Important examples of interaction of polymeric factors occur in **pericarp colour** of wheat grains.
- The colour of pericarp, depending upon the varieties may be **deep red, light red or white** (colourless).
- A cross between **deep red pericarp** variety and **white (colourless) pericarp** variety shows the following results: [See figure on next Page (bottom).]

  So in F_2 generation = 9 (Deep red) : 6 (Light red) : 1 (White). Thus here we see, when **both C_1 and C_2 are present, deep red pericarp is produced;** when **either C_1 or C_2 is present, light red pericarp is produced and in absence of C_1 and C_2, white or colourless** pericarp is produced. So C_1 and C_2 are **polymeric factors.**
- The traits or characters controlled by polymeric factors are known as **polygenic traits** and their inheritance is called **quantitative inheritance,** which can be explained on the basis of multiple factor or gene hypothesis.

Multiple genes are involved in inheritance of human-skin colour (Davenport, 1913), ear size in maize besides grain colour in wheat (Nilsson-Ehle, 1908). When these are controlled by two pairs of genes, the F_2 ratio appears as **1 : 4 : 6 : 4 : 1.**



♀ \ ♂	IP	Ip	IP	Ip
IP	IIPP (Green)	IIPp (Green)	IIPP (Green)	IIPp (Green)
Ip	IIPp (Green)	IIpp (Green)	IIPp (Green)	IIpp (Green)
IP	IIPP (Green)	IIPp (Green)	IIPP (Purple)	IIPp (Purple)
Ip	IIPp (Green)	IIpp (Green)	IIPp (Purple)	IIpp (Green)

Awned variety of wheat × Awnless variety of wheat

$A_1A_1A_2A_2$ × $a_1a_1a_2a_2$ — Parents

A_1A_2 a_1a_2 — Gametes

$A_1a_1A_2a_2$ (Awned) — F_1 gen.

Selling ⊗

♀ \ ♂	A_1A_2	A_1a_2	a_1A_2	a_1a_2
A_1A_2	$A_1A_1A_2A_2$ (Awned)	$A_1A_1A_2a_2$ (Awned)	$A_1a_1A_2A_2$ (Awned)	$A_1a_1A_2a_2$ (Awned)
A_1a_2	$A_1A_1A_2a_2$ (Awned)	$A_1A_1a_2a_2$ (Awned)	$A_1a_1A_2a_2$ (Awned)	$A_1a_1a_2a_2$ (Awned)
a_1A_2	$A_1a_1A_2A_2$ (Awned)	$A_1a_1A_2a_2$ (Awned)	$a_1a_1A_2A_2$ (Awned)	$a_1a_1A_2a_2$ (Awned)
a_1a_2	$A_1a_1A_2a_2$ (Awned)	$A_1a_1a_2a_2$ (Awned)	$a_1a_1A_2a_2$ (Awned)	$a_1a_1a_2a_2$ (Awnless)

— F_2 gen.

Awned : Awnless

15 : 1

Deep red pericarp variety × White pericarp variety

$C_1C_1C_2C_2$ × $c_1c_1c_2c_2$ — Parents

C_1C_2 c_1c_2 — Gametes

$C_1c_1C_2c_2$ (Deep red) — F_1 gen.

Selling ⊗

♀ \ ♂	C_1C_2	C_1c_2	c_1C_2	c_1c_2
C_1C_2	$C_1C_1C_2C_2$ (Deep red)	$C_1C_1C_2c_2$ (Deep red)	$C_1c_1C_2C_2$ (Deep red)	$C_1c_1C_2c_2$ (Deep red)
C_1c_2	$C_1C_1C_2c_2$ (Deep red)	$C_1C_1c_2c_2$ (Light red)	$C_1c_1C_2c_2$ (Deep red)	$C_1c_1c_2c_2$ (Light red)
c_1C_2	$C_1c_1C_2C_2$ (Deep red)	$C_1c_1C_2c_2$ (Deep red)	$c_1c_1C_2C_2$ (Light red)	$c_1c_1C_2c_2$ (Light red)
c_1c_2	$C_1c_1C_2c_2$ (Deep red)	$C_1c_1c_2c_2$ (Light red)	$c_1c_1C_2c_2$ (Light red)	$c_1c_1c_2c_2$ (White)

— F_2 gen.

SOME OTHER PATTERNS OF INHERITANCE

1. Multiple allelism

Alternative forms of same gene are called alleles or allelomorphs. Mendel's concept of inheritance is based on two alternative forms of a gene and hence two alleles are responsible for governing the same trait or character. But in post Mendelian period, it became clear that **a gene can have more than two alleles or allelomorphs,** which can be expected by mutation in wild form in more than one ways. These alleles or allelomorphs make a series of multiple alleles. There may or may not be a simple dominant-recessive relationship between different alleles but **their characteristic feature is that they are usually located on the same locus and hence there is absence of crossing over between them.** The mode of inheritance in case of multiple alleles is called **multiple allelism.** Multiple alleles can be found only in population and in any diploid individual, only two alleles can be found.

Examples of multiple alleles

- A well known and simplest example of multiple allelism is the inheritance of A, B, O blood groups in human beings. In human population, 3 different alleles for this character are found—I^A, I^B and I^O or i. I^A and I^B are mutant alleles and are dominant over I^O or i, which is wild allele. I^A and I^B are responsible for A and B antigens (glycoproteins) while I^O or i does not produce any of these A or B antigens. A person is having only two of these three alleles and blood type can be determined by their antigen types. Six genotypic combinations are possible with these three alleles.

Blood type (phenotype)	Genotype	Antigen	Antibodies
A	I^AI^A or I^AI^O	A	b
B	I^BI^B or I^BI^O	B	a
AB	I^AI^B	Both A and B	Neither a nor b
O	I^OI^O	Neither A nor B	Both a and b

- Alleles I^A and I^B are **codominant** as a person with genotype I^AI^B produces both A and B antigens. ABO blood groups in man have been established by **K. Landsteiner.** ABO blood grouping is thus **example of both multiple allelism and codominance.** With the help of blood typing, compatibility of blood types can be matched during blood transfusion and blood groups sometimes help to decide cases of disputed parentage.
- Other examples of multiple allelism are—
  - (i) Colour loci in corn
  - (ii) Skin colour in rodents
  - (iii) Eye colour in *Drosophila*
  - (iv) Self incompatibility genes in some plants.

2. Pleiotropy

Mendel considered that a single factor or gene controls a single character or trait or phenotype, but later on it was found that a phenotype or character can be influenced by many genes and a gene can influence many phenotypes or traits. **When a gene affects many aspects of phenotype or controls several phenotypes,** it is said to be **pleiotropic** (derived from Greek words which mean 'to take many turns') and this phenomenon is called **pleiotropy.** These pleiotropic genes, in addition to their main effect, may also act as modifiers for another entirely different gene and thus are having more than one effect.

- Interrelationship between different metabolic pathways contributing to different phenotypes is the basis of pleiotropy. Nowadays, it is believed that most of the genes (not all) affect more than one phenotypic traits and hence are pleiotropic.

Some examples of pleiotropy are:

(i) Gene for phenylketonuria in human beings also interferes with synthesis of melanin pigment which lightens the colour of the hair.

(ii) Hereditary disease, sickle-cell anemia (caused due to recessive gene) is also an example of pleiotropy.

(iii) Some genes for bristles, eye and wing in *Drosophila* may also affect the number of facets in bar-eyed flies.

(iv) Gene for white eyes in *Drosophila* may affect the shape of sperm-storage organs in females and also some other structures.

(v) In garden pea (*Pisum sativum*), same gene controls both seed coat colour and flower colour, hence pleiotropic in nature.

LINKAGE

Mendel's laws of inheritance are **applicable** to both **chromosomes and genes.** At the time of gamete formation, both maternal and paternal members of homologous chromosomes are independently distributed to gametes and hence the genes located on these chromosomes are also distributed independently.

- Mendel's law of independent assortment is **not universally** accepted and is applied only to genes present on different chromosomes and not to genes present on the same chromosome.

An **exception** to Mendel's law of independent assortment was reported by **Bateson and Punnett (1906),** who reported that the **two pairs of alleles** in *Lathyrus* (Sweet pea) do not show independent assortment. They crossed two varieties of sweet pea, one with **blue flowers and long pollens** (BBLL) and other with **red flowers and round pollens** (bbll). The results were:

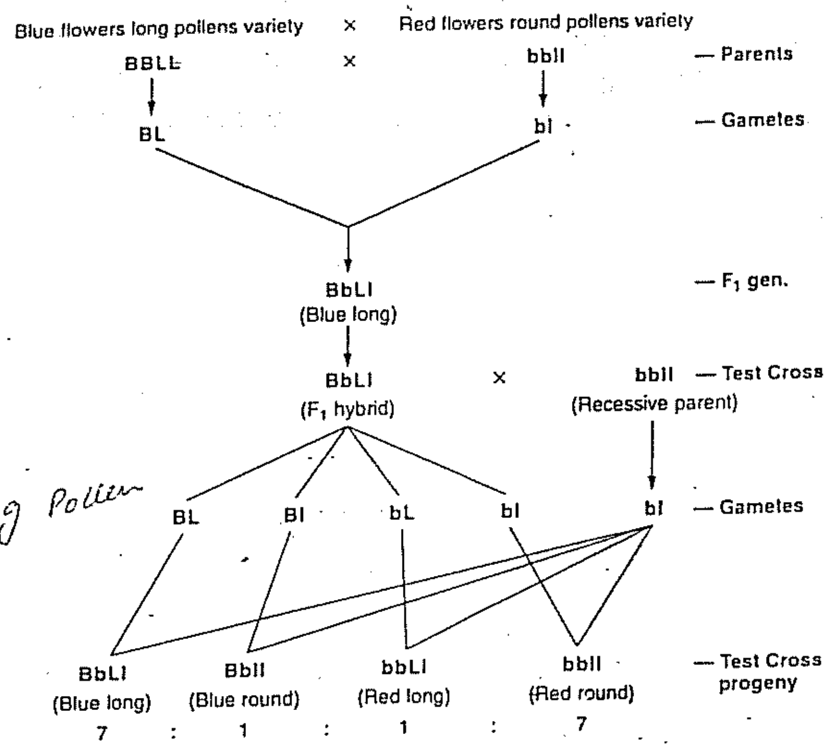
[See figure on next page (top).]

If there were independent assortment, the **test cross ratio** should have been **1 : 1 : 1 : 1,** but here **test cross ratio is found** to be **7 : 1 : 1 : 7,** *i.e.,* **parental combinations are in excess** (Blue long, red-round).

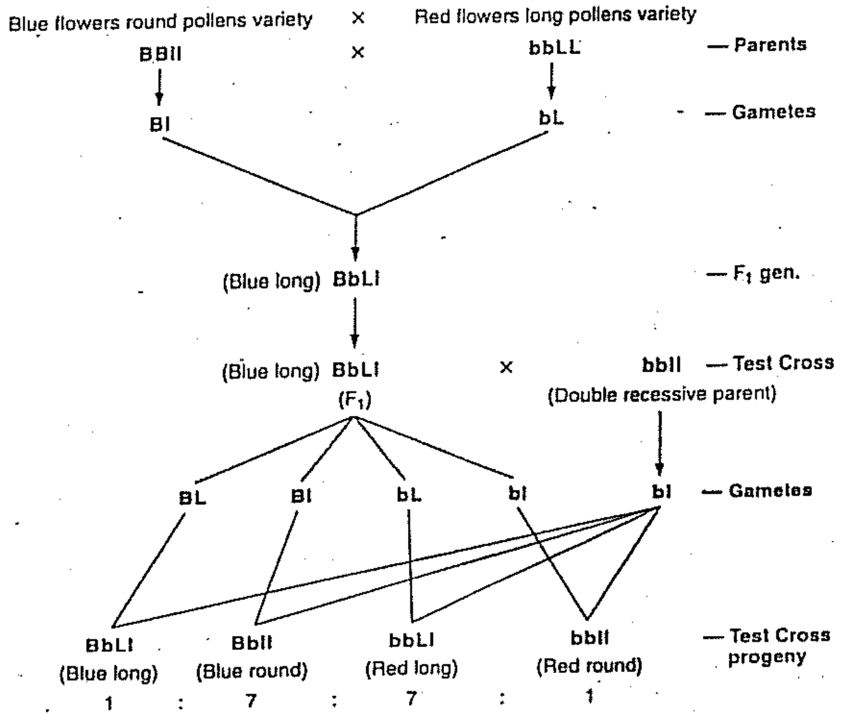
In this cross, the **two dominants enter from the same parent** and thus **they try to remain together.**

- **In second set of experiments,** Bateson and Punnett made a cross in which the **two dominants enter from the different parents,** *i.e.,*

[See figure on next page (bottom).]


Blue flowers long pollens variety × Red flowers round pollens variety
BBLL × bbll — Parents
BL bl — Gametes
BbLl (Blue long) — F₁ gen.
BbLl (F₁ hybrid) × bbll (Recessive parent) — Test Cross
BL Bl bL bl bl — Gametes
BbLl (Blue long) Bbll (Blue round) bbLl (Red long) bbll (Red round) — Test Cross progeny
7 : 1 : 1 : 7

blue flowers long Pollen variety.


Blue flowers round pollens variety × Red flowers long pollens variety
BBll × bbLL — Parents
Bl bL — Gametes
(Blue long) BbLl — F₁ gen.
(Blue long) BbLl (F₁) × bbll (Double recessive parent) — Test Cross
BL Bl bL bl bl — Gametes
BbLl (Blue long) Bbll (Blue round) bbLl (Red long) bbll (Red round) — Test Cross progeny
1 : 7 : 7 : 1

Again in this cross, test cross ratio comes out to be 1 : 7 : 7 : 1 (not 1 : 1 : 1 : 1). In this case also, **parental combinations are in excess** (blue round and red long). So **when the two dominants enter from the different parents, they try to remain separate.**

- **Bateson and Punnett** explained the above crosses as: When two dominants enter from the same parent, they try to remain together, which is called **'coupling'**. On the other hand, when two dominants enter from different parents, they try to remain separate, which is known as **'repulsion'**. **T.H. Morgan** (1910) reported the same thing in *Drosophila* and gave the term **Linkage** to this phenomenon. He also reported that **coupling and repulsion** are the two aspects of the linkage phenomenon.

Definition of linkage

"The tendency of parental combinations to remain together, which is expressed in terms of low frequency of recombinations (new combinations) is called linkage."

- Genes present on same chromosome thus show linkage. The parental combinations are due to linkage (new combinations or recombinations are due to crossing over).
- According to **T.H. Morgan:**

$$\text{Linkage} \propto \frac{1}{\text{distance between genes}}$$

i.e., linkage is **inversely proportional** to the distance between the genes on chromosomes. Thus degree of linkage is dependent upon distance between linked genes on the chromosomes. More the distance between the genes, lesser will be the degree or strength of linkage and *vice-versa*.

On the basis of the above finding, **Sturtevant** (1913) gave the theory of **'linear arrangement of genes'** on chromosomes, *i.e.*, genes are arranged on chromosome in **linear** manner or fashion.

Another example of linkage

Another example of linkage was reported by **Hutchinson** in *Zea mays* (maize). By crossing coloured and full endosperm variety with colourless shrinken variety and then by test crossing, he came to the conclusion that here again **parental combinations are in excess** (96.4%) which is due to linkage.

Significance of linkage

(i) The possibility of variations (variability) in gametes is reduced by linkage (unless crossing over occurs).

(ii) It provides a strong proof in favour of **linear arrangement of genes** on the chromosomes.

Linkage groups

All the genes linked together in a single chromosome (which do not show independent assortment), constitute a **linkage group** (Sutton, 1903).

- Number of linkage groups in an organism is equal to its **haploid number of chromosomes**, *e.g.*, In *Drosophila*, $n = 4$, hence **linkage groups = 4**. Similarly, in *Pisum sativum* (garden pea), $n = 7$, hence **linkage groups = 7**. In *Zea mays* (maize), $n = 10$, hence **linkage groups = 10**.
- Number of **linkage groups in prokaryotes** (bacteria, cyanobacteria or blue-green algae and mycoplasma) **is one**.

CROSSING OVER

According to T.H. Morgan, genes present on the same chromosome show linkage. Linkage may be **complete** (when only parental combinations are produced), *e.g.*, in male *Drosophila* or **incomplete** (when some recombinations are also produced along with parental combinations). The **recombinations** or new combinations are inturn produced by a process, called **crossing over.**

- **Thus crossing over is separation of linked genes (T.H. Morgan).**

Definition of crossing over

"The process which produces recombinations or new combinations of genes as a result of interchange of corresponding segments between non-sister chromatids of homologous chromosomes."

- Crossing over occurs at **pachytene** sub-stage of prophase I of meiosis (at molecular level), but visible at **diplotene** sub-stage of prophase I.
- **Chiasmata** are the points, where crossing over occurs.
- Crossing over ∝ distance between the linked genes, *i.e.*, more the distance between genes on the chromosomes, more will be the chances of crossing over.
- Crossing over may be **single, double** or **multiple** depending upon number of chiasmata which in turn depends upon length of the chromosome.
- Crossing over is mostly **two-stranded single crossing over** with very few exceptions (although occurs at 4-strand stage in pachytene, but only 2 chromatids form chiasma where exchange occurs).

Germinal and somatic crossing over

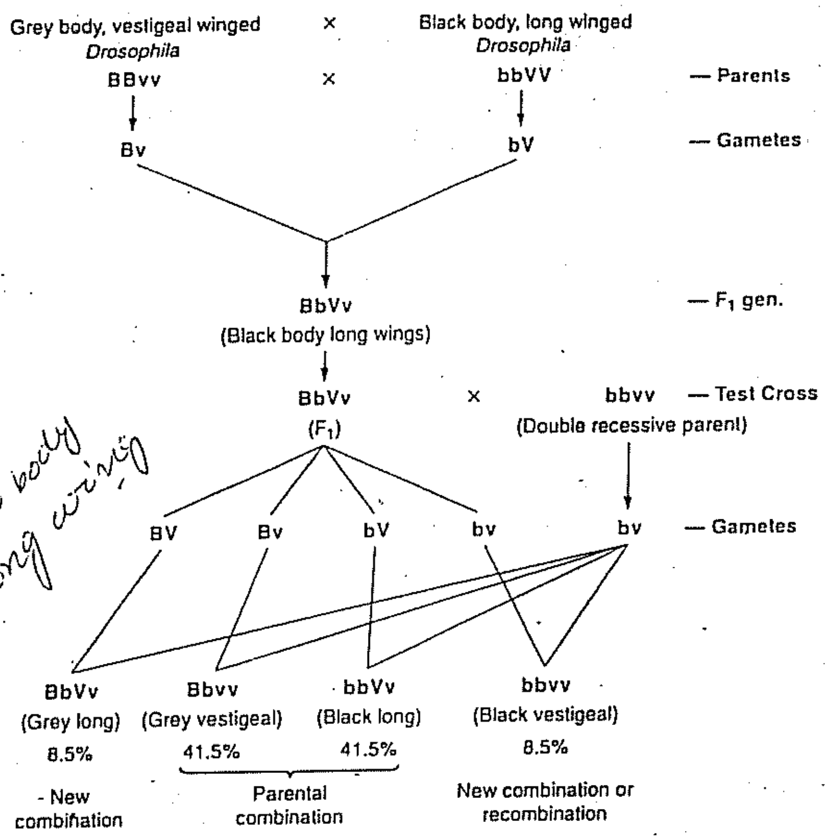
Germinal crossing over: Crossing over is common in **germinal cells** at the time of gamete formation (during meiosis) and it is called **meiotic crossing over** or **germinal crossing over** and is of great significance.

Somatic crossing over: Generally pairing of homologous chromosomes occurs in meiosis in germinal cells, but sometimes this pairing of chromosomes also occurs in **somatic cells** and crossing over also occurs, which is called **somatic crossing over.**

- This somatic crossing over has been reported in *Drosophila* by **C. Stern**, in maize by **Jones** and in *Aspergillus nidulans* (an ascomycetes fungus) by **G. Pontecorvo**. Somatic crossing over occurs rarely (low frequency) and the mechanism is similar to germinal crossing over.

Example of crossing over

Crossing over was reported in *Drosophila* by **T.H. Morgan** in the following cross:


Grey body, vestigeal winged
Drosophila
×
Black body, long winged
Drosophila
BBvv
×
bbVV
— Parents
Bv
bV
— Gametes
BbVv
(Black body long wings)
— F₁ gen.
BbVv
(F₁)
×
bbvv
— Test Cross
(Double recessive parent)
BV
Bv
bV
bv
bv
— Gametes
BbVv
(Grey long)
8.5%
Bbvv
(Grey vestigeal)
41.5%
bbVv
(Black long)
41.5%
bbvv
(Black vestigeal)
8.5%
- New combination
Parental combination
New combination or recombination

black body
long wing

of
homologous
non sister
chromatids

i.e., new combinations or recombinations have been reported in 17% cases, which are due to crossing over.

Theories regarding crossing over

Different theories of crossing over and chiasmata formation have been given as copy choice theory by **Belling**, **breakage first theory** by **Muller**, **contact first theory** by **Serebrousky**, etc. But the **most accepted theory** is **precosity theory** or **strain theory**, given by **C.D. Darlington**. According to this theory, as a result of twisting of homologous chromosomes, a strain develops which causes breakage of chromatids at the point of contact. The broken segments unite with other segments to bring about crossing over, *i.e.*, exchange of segments.

Factors affecting crossing over

(i) **Temperature:** Frequency of crossing over is increased by **high and low temp.**

(ii) **X-rays:** Frequency of crossing over is increased by X-rays.

(iii) **Radium radiations** also increase crossing over.

(iv) **Sex:** Crossing over is more in **females**.

(v) **Age:** Older females have more chances of crossing over.

Significance of crossing over

(i) Crossing over provides a strong proof in favour of linear arrangement of genes on the chromosomes.

(ii) **Linkage maps** or **genetic maps** are constructed on the basis of crossing over.

(iii) Recombinations or new gene combinations are produced due to crossing over, which change genetic pool by changing of gene frequency and this provides a way of **evolution** (micro evolution).

Crossing over and linkage maps

maps linkages

As recombination frequencies or cross over frequencies are directly proportional to distances between genes, hence these values are used in formation of **linkage maps**, *i.e.*, relative distances between the genes. In linkage map, one map unit (m.u.) is considered equal to 1% recombination. A map unit is sometimes called **centiMorgan** (cM) after the name of **Thomas Hunt Morgan.** However, linear relationship between cM units and cross over frequencies does not hold good for long distances on a map.

Recombination frequency or cross over frequency or percentage of non-parental combinations can be calculated by the following formula:

$$\frac{\text{Number of individuals showing recombinations}}{\text{Total number of offsprings}} \times 100.$$

For example: Individuals homozygous for cd genes were crossed with wild type (++). The F_1 dihybrid thus produced was test crossed and it produced offsprings in the following ratio:

crossing over
& linkage maps

++ — 900
cd — 880
+d — 115
+c — 105

What is the distance between c and d genes? (AIIMS 1990)

Solution: Here offsprings with parental combinations $= 900 + 880 = 1780$

Offsprings with non-parental combinations or with recombinations $= 115 + 105 = 220$

Total offsprings $= 1780 + 220 = 2000$

$\therefore$ Percentage of non-parental combination or

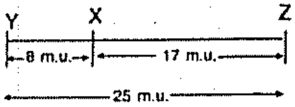
recombination frequency $= \frac{220}{2000} \times 100 = 11\%$

As recombination frequency is 11%, hence distance between genes c and d is 11 m.u. or cM.

- Further by determining the cross over percentage between genes, linear order of genes on chromosome can also be known.

For example: The cross over frequencies between the genes X and Y, X and Z and Y and Z are 8%, 17% and 25% respectively. What is the sequence of genes on chromosome?

Solution: From the recombination frequencies between different genes X, Y and Z, it is clear that distance between X and Y genes is 8 m.u., between X and Z is 17 m.u. and between Y and Z genes is 25 m.u. Hence linear order of genes on chromosome is:



STRUCTURAL CHANGES IN CHROMOSOMES

Structural changes in chromosomes may be present naturally or can be artificially induced.

There are **four types** of structural changes present in chromosomes:

1. Deficiency or deletion
2. Duplications or additions
3. Translocations
4. Inversions

1. Deficiency or Deletion

- In case of deficiency, there is **loss of a segment** (part) of the chromosome.
- For pairing, the normal chromosome of homologous pair will form a loop (pachytene configuration).
- A very important example of deficiency is **'cat like cry'** in children, which is associated with **microcephaly** (small head).

2. Duplications or Additions

In case of duplication, there is **addition of a part of the chromosome.**

- For normal pairing at pachytene (pachytene configuration), the **duplicating chromosome** of homologous pair will form a loop.
- Important example of duplication is **bar eye character** in *Drosophila.*

3. Translocations

Translocation may be defined as, "The process in which there is **mutual exchange** of chromosomal segments between **non-homologous chromosomes**". (In crossing over exchange between **homologous chromosomes** occurs).

- Translocation is also known as **'illegitimate crossing over'.**
- For pairing, the **translocation heterozygote** will form a plus-shaped (+) figure (pachytene configuration).
- Translocations were first of all observed in evening **primrose** *(Oenothera)* and these were considered as **mutations** by **Hugo de Vries** initially.
- Translocations in heterozygous condition are reported in *Oenothera, Rhoeo* and *Tradescantia.*

4. Inversions

In this case, the **chromosome breaks at two points,** the broken piece **rotates through 180°** and thus **reunites** in **reverse order.**

- For normal pairing, both the chromosomes of homologous pair will form loops.

Inversions are of 2 types:

(a) Paracentric inversion: If **centromere** or primary constriction **is not present** in inverted portion or segment, it is called paracentric inversion.

(b) Pericentric inversion: If **centromere is present** in inverted segment, it is called pericentric inversion.

- Translocations and inversions are associated with **poor seed setting** and considerable amount of **semisterility.**

NUMERICAL CHANGES IN CHROMOSOMES (HETEROPLOIDY)

Each organism is having definite number of chromosomes. Sometimes number of chromosomes is changed, which are called **numerical changes in chromosomes** or **heteroploidy.**

These changes in number of chromosomes are of 2 types:

(A) Aneuploidy and
(B) Euploidy.

(A) Aneuploidy

If the number of chromosomes in an organism is not whole number multiple of basic chromosome number, it is called **aneuploidy** and such organisms are called **aneuploids,** *e.g.,* if x (basic chromosomes no.) = 7 and $2n$ (diploid no.) = 14, then $2n = 15$, $2n = 16$, $2n = 13$, $2n = 12$, are the **aneuploids.**

Aneuploidy is of 4 different types:

1. Monosomy

The organisms (plants) having genetic constitution as $(2n - 1)$ *i.e.,* **lacking one complete chromosome,** are called **monosomics** and this phenomenon is known as **monosomy.**

- Number of monosomics possible in an organism is equal to its haploid number of chromosomes, *e.g.*, 21 monosomics were produced in wheat by E.R. Sears (as here $n = 21$).

- $2n - 1 - 1$ (not $2n - 2$) are called **double monosomics** (*i.e.*, the two chromosomes removed are not homologous).
- Monosomy cannot be tolerated in diploids.
- Important example of monosomy in human beings is **'Turner's syndrome'**, which is monosomic of XO type. These are sterile females and are having webbed neck.

2. Nullisomy

Organisms (plants) having genetic constitution as $(2n - 2)$, *i.e.*, **lacking a pair of homologous chromosomes, are called nullisomics and this condition is called nullisomy.**

- Number of nullisomics possible in a plant is again equal to its haploid number of chromosomes.

3. Trisomy

Organisms having genetic constitution as $(2n + 1)$, *i.e.*, having one extra chromosome, are called **trisomics** and this condition is called **trisomy**.

- Number of possible trisomics in an organism is equal to its haploid number of chromosomes.
- Trisomics were first of all obtained by **Blakeslee** *et al.* in **Jimson weed** *(Datura stramonium)*.
- Important examples of trisomy in human beings (*i.e.*, $2n = 47$) are:

(a) **Down's syndrome or Mongolian idiots** (Mongolism): This is **autosomal trisomic** for chromosome 21, which was reported by **Langdon Down of England** in 1886. These are **short-statured, having heavy eyelids and heavy tongue, low mental ability and life of 8–12 years.**

(b) **Klinefelter's syndrome** (trisomy of XXY type): These are **normal males but having low sperm count** (sterile).

4. Tetrasomy

Organisms having genetic constitution as $(2n + 2)$, *i.e.*, one **homologous pair of chromosomes extra** or a particular chromosome is present in four doses.

(B) Euploidy

The organisms having **one or more complete sets** of chromosomes or organisms having chromosome number which is **whole number multiple of basic chromosome number**, are called **euploids** and this phenomenon is called **euploidy**.

e.g., x (basic chromosome no.) = 7.

$$\text{Thus,}\quad \left.\begin{array}{l} 2n = 2x = 14 \text{ (Diploid)} \\ 2n = 3x = 21 \text{ (Triploid)} \\ 2n = 6x = 42 \text{ (Hexaploid)} \end{array}\right\} \text{Euploids}$$

Euploidy may be of following types:

1. Haploidy and monoploidy

Haploids are the individuals, which are having half the chromosome number (somatic) as compared to its diploid or normal individual, *e.g.*, **in wheat**,

$$2n = 6x = 42 \text{ (Hexaploid wheat)}$$

$$\text{Thus,}\quad 2n = 3x = 21 \text{ (Haploid)}$$

- **Monoploids** on the other hand are the individuals having **single basic set of chromosomes**, *e.g.*,
  in **barley**, $2n = x = 7$ (Monoploid)
  in **maize**, $2n = x = 10$ (Monoploid)
  ($x \rightarrow$ basic chromosome number).
- **In haploids**, there is **reduction in size** of vegetative and reproductive parts (*e.g.*, stomatal size, pollen size and seed size, etc.).
- Best method of haploid production is **pollen culture.**
- Haploids are very useful in studies on mutation, because a minute change can be detected in them due to presence of single set of chromosomes. Secondly, by doubling their chromosome number by colchicine treatment, **homozygous diploids** are produced, which are used as **new varieties** or **used as one of the parents in hybridization experiments.**

2. Polyploidy

Organisms or individuals having **many complete sets** of chromosomes are known as **polyploids** and this phenomenon is called **polyploidy**. Polyploidy is of 3 types:

(i) Autopolyploidy,

(ii) Allopolyploidy and

(iii) Segmental polyploidy or autoallopolyploidy.

(i) **Autopolyploidy:** Here, there is multiplication of **same basic set of chromosomes.**

- Organism with single genome, *i.e.*, 'A'—**haploid.**
- Organism with two similar genomes, *i.e.*, 'AA'—**autodiploid.**
- Organism with three similar genomes, *i.e.*, 'AAA'—**autotriploid.**
- Organism with four similar genomes, *i.e.*, AAAA—**autotetraploid** and so on.
- Autopolyploids are **present naturally** and can also be **produced artificially.**
- **Natural autopolyploids** are found in **apple, banana, doob grass** *(Cynodon dactylon)*, **grapes, tomato, watermelons, oenothera, maize, barseem, marigold,** etc.
- Polyploidy can be induced artificially by **colchicine treatment** in 0.01–0.5% concentration. Colchicine is an **alkaloid** obtained from **seeds and corms** of *Colchicum autumnale*, a plant belonging to family **Liliaceae** (first obtained by **Houde**, 1887 and was first used for inducing polyploidy by **Dustin**, 1934).
- Colchicine induces cell division without cytokinesis (cell wall formation), because of its property of **arresting and breaking the spindle.** Thus doubling of chromosome number occurs.

  Colchicine treatment for inducing polyploidy can be given in either of the following ways:

  (a) By soaking seeds in its solution.

  (b) By placing cotton soaked in colchicine solution on axillary bud.

  (c) By injecting colchicine solution into the seedlings.
- Colchicine has **no effect on its parent plant** *(Colchicum)* because of presence of anticolchicine in it (Blakeslee).

- (Colchicine is also having medicinal property, *i.e.*, used in rheumatism).
- In polyploids there is enlargement of vegetative and reproductive parts (*i.e.*, **gigantism**).

Some other features of polyploids are:

(a) Due to increase in cell size, water content is increased which leads to decrease in osmotic pressure, due to which cold and frost resistance are decreased in them.

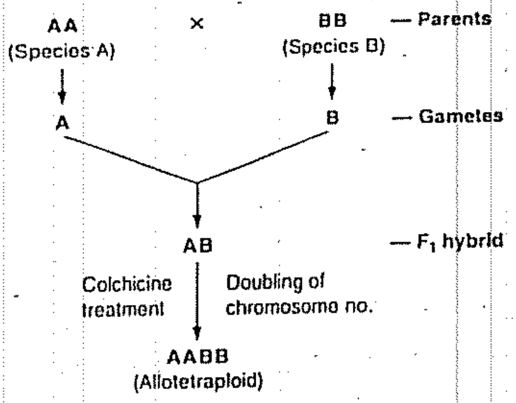
(b) Slower growth rate due to decreased rate of cell division.

(c) Delayed flowering.

(d) Even death occurs at higher ploidy levels.

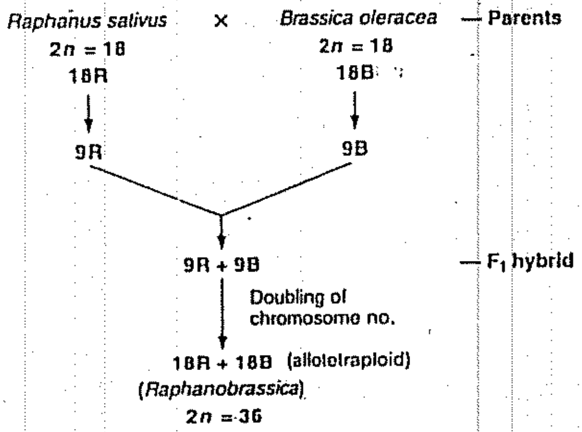
(e) Sterility and poor seed setting.

(II) **Allopolyploidy:** Allopolyploidy is induced by doubling the chromosome number of the hybrid, produced by crossing two different plant sps., *e.g.*,


AA
(Species A)
×
BB
(Species B)
— Parents
A
B
— Gametes
AB
— F_1 hybrid
Colchicine treatment
Doubling of chromosome no.
AABB
(Allotetraploid)

Some classical examples of allopolyploids are:

(a) ***Raphanobrassica*:** This allopolyploid was produced by **G.D. Karpechenko** (1927) by doubling the chromosome no. of F_1 hybrid produced by crossing **radish** (*Raphanus sativus*) and **cabbage** (*Brassica oleracea*). **This cross was made to produce a new plant with roots like radish and upper portion like cabbage,** *i.e.*,

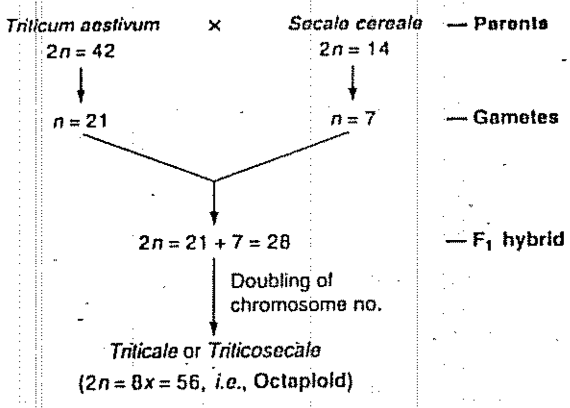

Raphanus sativus
$2n = 18$
18R
×
Brassica oleracea
$2n = 18$
18B
— Parents
9R
9B
9R + 9B
— F_1 hybrid
Doubling of chromosome no.
18R + 18B (allotetraploid)
(*Raphanobrassica*)
$2n = 36$

But it proved useless, because as against intention, the roots of this new plant were like cabbage and upper part like radish.

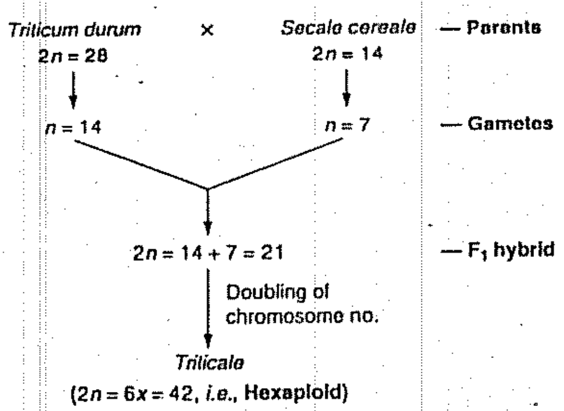
(b) ***Triticale* or *Triticosecale*:**

- **This is first man made crop or cereal, produced by Rimpau.**
- Triticale is an example of artificial allopolyploid, produced by crossing wheat (*Triticum*) and European rye (*Secale*), *i.e.*, intergeneric hybridization.
- Triticale may be hexaploid or octaploid, on the basis of type of wheat used in hybridization (*i.e.*, tetraploid wheat or hexaploid wheat).

Octaploid *Triticale* :


Triticum aestivum
$2n = 42$
×
Secale cereale
$2n = 14$
— Parents
$n = 21$
$n = 7$
— Gametes
$2n = 21 + 7 = 28$
— F_1 hybrid
Doubling of chromosome no.
Triticale or *Triticosecale*
($2n = 8x = 56$, *i.e.*, Octaploid)

Hexaploid *Triticale* :


Triticum durum
$2n = 28$
×
Secale cereale
$2n = 14$
— Parents
$n = 14$
$n = 7$
— Gametes
$2n = 14 + 7 = 21$
— F_1 hybrid
Doubling of chromosome no.
Triticale
($2n = 6x = 42$, *i.e.*, Hexaploid)

Wheat: Common wheat (*Triticum aestivum*) is an important example of natural allopolyploid.

- Common wheat is **hexaploid** ($2n = 6x = 42$) with **three genomes, A, B and D, *i.e.*, AABBDD.**

These three genomes are derived from three different diploid species as:

(i) *Triticum aegilopoides*—AA ($2n = 14$),

(ii) *Aegilops speltoides*—BB ($2n = 14$),

(iii) *Aegilops squarossa*—DD ($2n = 14$).

- By crossing of first two diploid sps., *Triticum dicoccoides* ($2n = 4x = 28$, *i.e.*, **tetraploid—AABB**) is produced, which on crossing with third species gives rise to *Triticum aestivum* ($2n = 6x = 42$, *i.e.*, **hexaploid—AABBDD**).

(iii) Autoallopolyploidy or Segmental polyploidy: This is intermediate between the first two types.

- o Wheat is nowadays considered to be an example of **segmental polyploidy** rather than allopolyploidy as earlier thought, because **three genomes in wheat A, B and D** are not fully distinct from each other and they have some portions common in them (*i.e.*, only segments are homologous). Hence A, B and D show **homoeologous** relationship (not homologous), so pairing can occur upto some extent. Such polyploids where different genomes show homoeologous relationship are called **autoallopolyploids** or **segmental polyploids.**

MUTATIONS

The term **'mutation'** was first used in *Oenothera lamarckiana* by **Hugo de Vries** (1900) for **'sudden phenotypic changes which are heritable'.**

- Darwin called these mutations as **'sports'.**

Nowadays, this term mutation is used in strict sense for the changes in the chemical structure of genes at molecular level, which are called gene mutations or point mutations.

- Phenotypic changes which are produced by **gene mutations are reversible**, whereas phenotypic changes due to structural and numerical changes in chromosomes are **irreversible.**

Most of the earlier examples of mutations given by Hugo de Vries in *Oenothera* were due to structural and numerical changes in chromosomes, *e.g.*, in *Oenothera*, **'gigas'** mutant is a polyploid.

History: Earliest gene mutation was recorded by **Seth Wright** (1791), when he observed short-legged lamb (Ancon sheep) in his flock.

- **First scientific study of mutation was made by T.H.Morgan** (1910) in *Drosophila*. Later on in *Drosophila*, more studies were made and now about **500 mutations** are known in *Drosophila* alone.

In last 25 years, most of the studies related to mutations have been made in micro-organisms, *e.g.*, in *Neurospora* (Red mould), *E. coli (Escherichia coli)* and **bacteriophages** (viruses, infecting bacteria).

- Range of mutations is from very small to large, *e.g.*, in *Neurospora*, there is no structural change and only modification of nutritional requirement occurs, whereas in **ancon sheep**, mutation is large.

Stage at which mutation occurs: At any stage, *e.g.*,

(a) Before formation of gametes: All the organisms resulting from these gametes will be affected.

(b) In gametes or zygote: Only one organism will be affected.

(c) In zygote, when it has undergone some divisions, only organs will be affected.

Frequency of mutations or Mutation rate at a particular gene locus: Some genes are stable, which have low frequency of mutation and some are unstable, which have high frequency of mutation.

- In *Drosophila*, frequency of mutation is 1 in 1,00,000 or 1×10^{-5}.
- General range is 1 in 20,000 to 1 in 2,00,000.
- Mutations are spontaneous (which occur spontaneously in nature) and also **induced** (which can be produced artificially by certain mutagenic agents or **mutagens.**)

Mutagens are of 2 types:

1. Physical mutagens or radiations, *e.g.*, X-rays, β-rays, γ-rays, UV-rays, etc.

- Use of X-rays as mutagenic agent was first shown by **H.J. Muller** (1927) in *Drosophila* and later on by **L.J. Stadler** (1928) in maize and barley.

Radiations are of further 2 types:

(a) Ionizing radiations, *e.g.*, X-rays, β-rays, γ-rays. These have high penetrating power.

(b) Non-ionizing radiations, *e.g.*, UV-rays (first used by Altenburg, 1930). They have low penetrating power.

- X-rays, β-rays and γ-rays are used as mutagens in such materials, where nucleus is deep seated, *e.g.*, seeds, stem cutting, etc., whereas UV-rays are used in micro-organisms, pollens, etc. (where nuclei are near the surface).

2. Chemical mutagens: Use of chemicals for inducing mutations was first made by **C. Auerbach** during World war II. She used **mustard gas** (having delayed effect after 2, 3 generation), ethyl urethane, formaldehyde, phenol, etc. Other chemicals, which are being used as mutagens nowadays are: maleic hydrazide, hydroxylamine, hydrazine, nitrous acid, methyl methane sulphonate (MMS) and ethyl methane sulphonate (EMS), etc.

- o (EMS is the most extensively used chemical mutagen in different crop plants nowadays.)

Practical Importance of mutations

Different varieties in different crop plants have been obtained by mutation. Mutations are generally **deleterious and recessive,** but according to **Gustaffson,** one in 1000 or more mutations may be useful and this has no match. *e.g.*,

1. In Wheat: 'Sharbati Sonora' variety in wheat has been developed by γ-rays mutation on Sonora-64 variety (Mexican dwarf wheat variety).

- o **Sharbati Sonora** variety was developed by **Dr. M.S. Swaminathan** (former Director General of IRRI Manila, Philippines). This variety is responsible for **Green Revolution in India.**

2. In Rice: Reimei variety.

3. In Barley: Erectoids and **Erectiferum** varieties.

4. In Peppermint (crystallized oil obtained from *Mentha piperita* of family **Labiatae**): **'Todd's Mitcham'** variety (highly disease resistant and with high oil content).

5. In Castor (*Ricinus communis*): **'Aruna'** variety has been developed by mutation, where maturity period has been reduced from normal 270 days to 102 days.

6. **Penicillin** (antibiotic discovered by Sir Alexander Fleming). Its production has been increased enormously by UV-rays treatment on *Penicillium notatum* and *P. chrysogenum* (Ascomycetes fungus).

Besides these, a number of other varieties have been produced in different plants.

Mutation at molecular level (*i.e.*, Permanent alteration in nucleotides or bases in DNA): In these **base pair replacements** are very common, which are of 2 types:

(i) **Transitions:** When one purine is replaced by another purine or one pyrimidine is replaced by another pyrimidine, these base pair replacements are called **transitions.**

- Transitions are caused by **base analogues, alkylating agents** (MMS, EMS), **nitrous acid** and **hydroxylamine.**
- Base analogues of thymine are:
  (a) **5-bromo uracil** (Bu)
  (b) **Bromodeoxyuridine** (BudR)
  (c) **5-iodouracil**
  (d) **5-chlorouracil**
  Similarly **2-amino purine** is base analogue of **adenine** (6-amino purine).

(ii) **Transversions:** When purine is replaced by pyrimidine and *vice-versa*, such base pair replacements are called **transversions.**

- Transitions are more common in nature than transversions.

Frameshift mutations

Genetic information in DNA is present in the form of triplet codons (3 letter codon) which constitute **'Reading frame'**. Sometimes this **reading frame** is changed due to addition or deletion of a single or more N-bases, which is called **frameshift mutation.**

- o **Frameshift mutations** are caused by **acridine dyes** (Proflavin and acridine orange), which have the capacity of either adding or deleting a single base or nucleotide, *e.g.*,

  Wild type or normal type (DNA) :

  TAC TCC CGA ACG ATA CCA GAG ...

  Addition (frameshift):

  ↓+T

  TAC TTC CCG AAC GAT ACC AGA ...

  Deletion (frameshift) :

  ↓–G

  TAC TCC CGA ACA TAC CAG AG ...

- o **Frameshift mutations** can be changed to normal (wild) by crossing two frameshift mutations.

Hardy Weinberg law

Hardy (English mathematician) and **Weinberg** (German botanist) gave this law in 1908. According to this, "Gene frequencies remain unaltered from generation to generation irrespective of dominant and recessive relationships".

Or

"The mutations, which are not dominant, are not lost from the gene pool of the organism".

CYTOPLASMIC INHERITANCE OR EXTRANUCLEAR INHERITANCE

In some cases, nuclear inheritance is associated with cytoplasmic inheritance.

- Totality of hereditary material present in cytoplasm is known as **Plasmon** (unit-plasma genes). Cytoplasmic inheritance is mainly **maternal** (because egg provides more cytoplasm to zygote).

Examples:

1. Plastid inheritance in *Mirabilis jalapa* (4 o'clock plant).
2. 'Iojap' character in maize (Strips of white and green colours are present on leaves).
   - Iojap character once inherited through female parent will be able to maintain itself in the cytoplasm irrespective of genotype of the plant.
3. 'Petite' character in yeast (mitochondrial inheritanee).
   - Petite mutants in yeast are unable to grow on carbon sources (like glucose) and produce smaller colonies when grown on sugars like glucose. This difference is observed only in presence of oxygen (they have defective aerobic respiratory mechanism).
4. Coiling of shells in snails (Dextral or sinistral).
5. Inheritance of 'Kappa' particles in *Paramoecium.*
   - Kappa particles are present in some killer strains of *Paramoecium* and these are responsible for production of a substance **paramecin,** which is toxic to sensitive strain (not having kappa particles).
6. Male sterility in maize.
   - It was reported by **Rhoades** (1933) that male sterility in maize was contributed by female parent (nuclear genes having no influence). This was shown by crossing male sterile plants with wide range of fertile males and by observing all male sterile progenies in subsequent generations.
7. Inheritance of **poky** in *Neurospora* (mitochondrial inheritance).
   - A mutant of *Neurospora crassa* (obtained by **Mitchell,** 1952), which is very slow growing due to imbalance in mitochondrial physiology is called **poky.**

SEX LINKED TRAITS AND THEIR INHERITANCE

The traits which are carried on sex chromosomes are called sex linked traits and their inheritance is called sex linked inheritance.

- First case of sex linked (X-linked) trait was observed in *Drosophila* **(fruitfly)** by **T.H. Morgan** (1910), when he observed **rare white eyed fly** among red eyed flies. This was due to mutation. (Red is dominant over white)

Inheritance of X-linked gene for eye colour in *Drosophila*

(i) **Red eyed ♀ × white eyed ♂:** When red eyed (wild type) female fly is crossed with white eyed male fly (mutant), all male and female flies in F_1 generation have red eyes. On intercrossing of red eyed male and red eyed female flies of F_1 generation, in F_2 generation, female flies are exclusively red eyed but in male flies, 50% are red eyed and 50% white eyed (*i.e.*, red eyed and white eyed flies are in ratio 3 : 1).

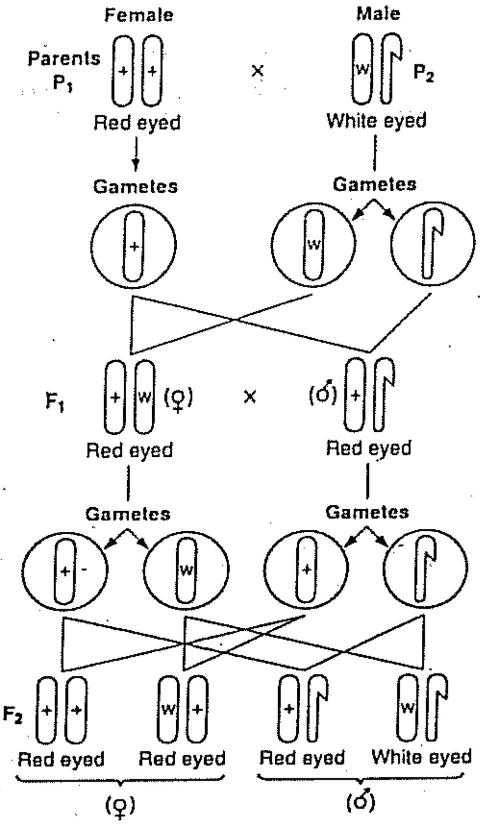

Female
Male
Parents
P_1
+
+
×
w
P_2
Red eyed
White eyed
Gametes
Gametes
+
w
F_1
+
w
(♀)
×
(♂)
+
Red eyed
Red eyed
Gametes
Gametes
+
w
+
F_2
+
+
w
+
+
w
Red eyed
Red eyed
Red eyed
White eyed
(♀)
(♂)

Fig. 8.1. Inheritance of eye-colour in *Drosophila*, when red eyed female is crossed with white eyed male-

(ii) White eyed ♀ × red eyed ♂: When a white eyed female fly is crossed with red eyed male fly, all female flies in F_1 gen. are red eyed and all male flies are white eyed. On intercrossing of F_1 gen., 50% female flies will be red eyed and 50% are white eyed. Similar is the case with male flies of F_2 gen.

So here we see that this X-linked or sex linked gene has a characteristic inheritance pattern, which is called **'criss-cross inheritance'**. Hence the X-linked gene is transmitted from father **to grandsons through its carrier daughters.**

- (White eyed male fly has a single gene 'w' (for white eye colour) on X-chromosome, *i.e.*, **one allelic condition**, which is called **hemizygous condition**). (See Fig. 8.2).

In human beings: Two important characters of sex linked (X-linked) inheritance are:

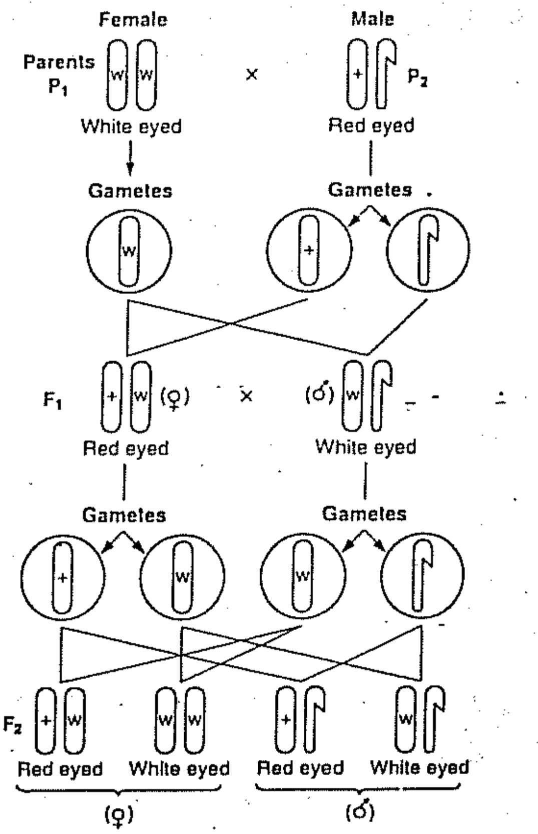

Female
Male
Parents
P_1
w
w
×
+
P_2
White eyed
Red eyed
Gametes
Gametes
w
+
F_1
+
w
(♀)
×
(♂)
w
Red eyed
White eyed
Gametes
Gametes
+
w
w
F_2
+
w
w
w
+
w
Red eyed
White eyed
Red eyed
White eyed
(♀)
(♂)

Fig. 8.2. Inheritance of eye colour in *Drosophila*, when white eyed female is crossed with red eyed male

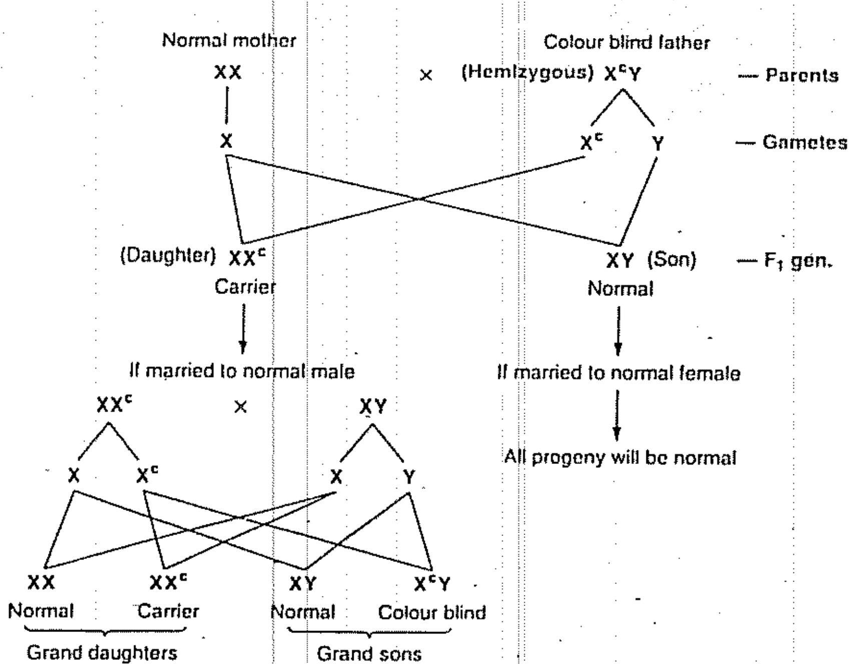
1. Colour blindness (Red-green blindness),
2. Haemophilia (Bleeder's disease).

1. Colour blindness or Red green blindness: It is due to recessive gene on X-chromosome. The persons suffering from this disease are unable to distinguish red and green colours due to absence of some colour-sensitive cells in retina.

Inheritance of colour blindness can be understood by the example given in diagram given on top of next page.

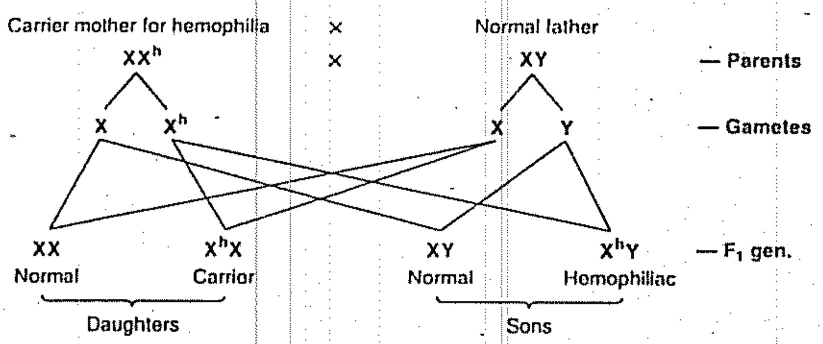
This is SKIP generation transmission of sex-linked characters.

2. Haemophilia: It is another most serious sex-linked disease in human beings. It is also called bleeder's disease. This is due to presence of a recessive gene on X-chromosome. The persons with this disease have blood which does not clot properly, *i.e.*, lacking a factor which is responsible for clotting of blood. Normally blood clotting occurs within 2–8 minutes after injury, but in persons with haemophilia, the time taken is 30 minutes to 24 hrs.


Normal mother
XX
Colour blind father
(Hemizygous) X^cY
×
— Parents
X
X^c
Y
— Gametes
(Daughter) XX^c
Carrier
XY (Son)
Normal
— F_1 gen.
If married to normal male
If married to normal female
All progeny will be normal
XX^c
×
XY
X
X^c
X
Y
XX
Normal
XX^c
Carrier
XY
Normal
X^cY
Colour blind
Grand daughters
Grand sons

- This disease is common in royal families of Russia and England.

Inheritance of this disease can be understood as:


Carrier mother for hemophilia
×
Normal father
XX^h
×
XY
— Parents
X
X^h
X
Y
— Gametes
XX
Normal
X^hX
Carrier
XY
Normal
X^hY
Hemophiliac
— F_1 gen.
Daughters
Sons

i.e., disease is transmitted to 50% of sons, even if father is **normal** and mother is **carrier.**

Inheritance of Y-linked genes

There are a few genes in the non-homologous portion of Y-chromosome of male, called **Y-linked genes** or **holandric** genes. These are transmitted directly **from father to son.** Characteristic example of **holandric** genes is **hypertrichosis** (long hair growth of ears), discovered by **Stern** (1926).

Sex influenced genes

Some genes may be present on autosomes or on sex-chromosomes, but their expression is **influenced by sex of the bearer,** which are called **sex-influenced genes.**

- Characteristic example of these in human beings is **pattern baldness.** The gene for baldness is found to be dominant in males and recessive in females, whereas in heterozygous condition, it is expressed in presence of only male hormones.

Sex linked lethal genes or Lethals

There are some **sex linked genes** which cause **lethality** or death of organism; these are called **sex linked lethals.** Two such sex linked lethals in human beings are genes for **haemophilia** and **pseudohypertrophic muscular distrophy.**

SEX-DETERMINATION

Sex determination is the process by which a spore or egg develops the characters of one or other sex. It is now believed that sex-determination occurs at the time of fusion of egg (female gamete) and sperm (syngamic concept). Sex differentiation, on the other hand, occurs after the embryo has obtained some age.

Thus sex-determination is the process which determines **fate of a fertilized egg.** In the past, there were some old ideas in relation to sex determination, but now **chromosome theory of sex determination** is accepted. This theory was put forward by McClung (1902). According to this theory, **chromosomes play a major role** in determination of sex in most of the dioecious organisms. The chromosomes are of 2 types—autosomes and sex-chromosomes.

Based on chromosome theory of sex-determination, main types are as follows:

1. **XX-XO type:** Here male is **digametic** (AA + X), *i.e.*, produces two types of gametes and **female is monogametic** (AA + XX), *i.e.*, produces only one type of gametes. Thus this type is based on **numerical number of chromosomes**, *e.g.*, in grasshopper and in plant kingdom in *Dioscorea sinuta* and *Vallisneria spiralis*.

2. **XX-XY type:** It is most common in plants and animals, *e.g.*, in all mammals including man and among plants in *Melandrium album*, *M. rubrum*, *Elodea*, *Rumex angiocarpus*, *Populus*, *Salix*, *Smilax*, *Morus*, *Canabis*, etc.

Here **male parent** is having two sex chromosomes (X and Y), besides autosomes and female parent is having two sex-chromosomes (XX) besides autosomes, *i.e.*, difference in structure of sex-chromosomes is there. Here the sex depends upon which of the two sperms fertilizes the egg (as **female is monogametic** and **male is digametic**).

Genic balance theory of sex-determination

After the discovery of Patterson, *i.e.*, Y-chromosome does not play significant role in sex-determination, C.B. Bridges (1921) gave **Genic balance theory** for sex-determination in *Drosophila*. According to him, **X-chromosomes are carriers of genes for femaleness and autosomes are carrier of genes for maleness**; so it is the **ratio of number of X-chromosomes and autosomal sets**, which determines sex. It can be explained by the following table:

S.No.	Chromosomal constitution	X/A ratio	Sex
1.	AA + XXX	1·5	Super female
2.	AAAA + XXXX	1·0	Normal female (tetraploid)
3.	AAA + XXX	1·0	Normal female (triploid)
4.	AA + XX	1·0	Normal female (diploid)
5.	AAA + XX	0·67	Intersex
6.	AAAA + XXX	0·75	Intersex
7.	AA + X	0·50	Normal male
8.	AAA + X	0·33	Super male

So it is clear, if ratio between X-chromosomes and autosomes is 0.5, **normal male** is developed and if ratio is 1.0, **normal female** is developed.

Sex determination in plants

Like human beings, sex in plants is mainly determined by Y-chromosome. In presence of Y-chromosomes (besides number of X-chromosomes and autosomes), plant will be male and in absence of Y-chromosome, plant will be female. Detailed study of sex-determination in plants has been made in *Coccinia* **(Kandoori)** and *Melandrium* **(Lychnis)**.

Sex determination mechanism in *Coccinia indica* (fam. Cucurbitaceae) has been studied in detail by **Prof. R.P. Roy** *et al.* (1951) at Patna University. It has been observed that in this plant, **presence of single Y-chromosome is responsible for maleness of plant**, irrespective of X/A ratio.

Similarly, sex determination in *Melandrium album* (fam. Caryophyllaceae) has been studied in detail by H.E. Warmke (1946). After study of diploid, triploid and tetraploid plants with respect to their sex, it has been observed that presence of one or more Y-chromosomes leads to formation of male plants and absence of Y-chromosomes leads to formation of female plant. However, when the ratio of Y : X is 1 : 4, some female potentialities develop in presence of Y-chromosome. Autosomes have no visible effect on sex. Further, Y-chromosome is longer than X-chromosome in *Melandrium*.

- o So here we observe that in *Melandrium* and *Coccinia*, **genes for maleness are present on Y-chromosome** (while these are present on autosomes in *Drosophila*).

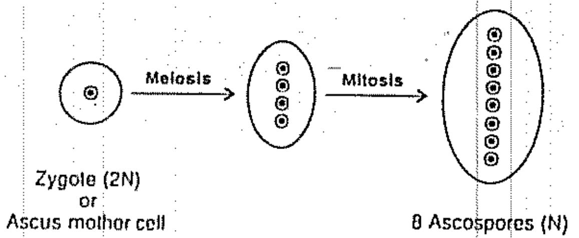
NEUROSPORA GENETICS

Q *Neurospora crassa* is commonly called Pink/Red bread mould (or Pink or Red mould).

It belongs to class **ascomycetes** of fungi (Sac fungi).

- It is used as experimental material in genetics as:
  - (i) It can be grown easily in a defined medium in laboratory.
  - (ii) It is a **haploid fungus** ($n = 7$); so each gene whether recessive or dominant expresses itself.
  - (iii) It has a short life cycle of 10 days.
  - (iv) The product of single meiosis can be easily analysed in *Neurospora*.
  - (v) Meiotic products are linearly arranged in the form of **ordered tetrads** (*i.e.*, the 8 ascospores formed are linearly arranged in ascus (sac-like structure), hence difference can be made between 'first division segregation' (when crossing over is absent) and 'second division segregation' (when crossing over takes place) and thus crossing over between centromere and a gene can be detected.
- *Neurospora crassa* was discovered by **Shear and Dodge** (Father of *Neurospora* genetics).
- As *Neurospora* is extensively used in genetical studies, hence it is called ***Drosophila* of Plant Kingdom.**

Neurospora is a **heterothallic fungus** having + and – mycelia (hyphae). Somatogamous fusion between two oppositely strained hyphal cells leads to fusion of two haploid nuclei and thus diploid zygote is formed. The zygote (acts as ascus mother cell) undergoes one meiotic division followed by mitotic division; so eight haploid nuclei are formed. Each nucleus gets surrounded by cytoplasm and converts into ascospore. In this way, eight nuclei form eight ascospores which are arranged **linearly** (although it is octad but commonly called tetrad—**ordered tetrad**). The fruiting body formed later in sexual reproduction is **flask-shaped or Perithecium.**



These ascospores are analysed to study and understand linkage and crossing over phenomena (Tetrad analysis).

- Red mould or *Neurospora* is very good material to study whether crossing over occurs at two-stranded or four-stranded stage. Bridges (1916) was the first to suggest that crossing over perhaps occurs at 4-stranded stage. **Lindegren** (1933) using *Neurospora crassa* reported that crossing over occurs at 4-stranded stage.

If crossing over occurs at 2-stranded stage: Suppose two allelic pairs of genes Aa and Bb are present on two chromosomes of zygotic cell or ascus mother cell and crossing over occurs in these allelic pairs of genes at 2-stranded stage (bivalent stage), the ascospores would show 4aB + 4Ab arrangement, *i.e.*, aB, aB, aB, aB, Ab, Ab, Ab, Ab arrangement as shown in Fig. 8.3.

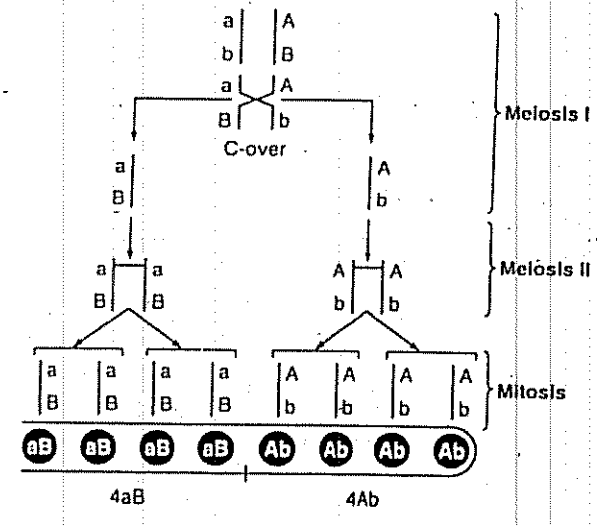


Fig. 8.3. Crossing over shown at 2-stranded stage

If crossing over occurs at 4-stranded stage: If crossing over occurs in two allelic pairs of genes at 4-stranded stage (tetrad stage), the ascospores would show 2AB + 2Ab + 2aB + 2ab arrangement as shown in Fig. 8.4.

Tetrad analysis in *Neurospora* has shown 2 : 2 : 2 : 2 arrangement and thus it is confirmed that crossing over occurs at 4-stranded stage (not at 2-stranded stage).

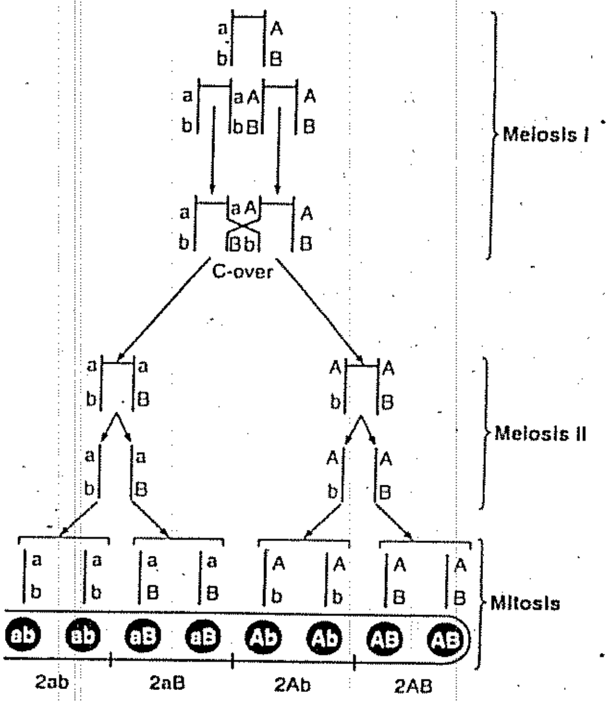


Fig. 8.4. Crossing over shown at 4-stranded stage

Biochemical mutations in *Neurospora*

Beadle and Tatum (1941) induced nutritional or biochemical mutations in conidia of *Neurospora crassa* and *N. sitophila* by X-rays or UV-rays and on the basis of these studies, they gave **'one-gene one-enzyme'** theory for which they were awarded **Nobel Prize** (1958) (see details under gene action in Chapter 7).

- This one gene one enzyme theory has been changed to **one-gene one-polypeptide** hypothesis, proposed by **Yanofsky**, *i.e.*, one gene synthesizes one polypeptide and many polypeptides form one enzyme.
- (**Jacobson and Baltimore** proposed **one m-RNA-one polypeptide** hypothesis whereas **de Vries** proposed **one gene one character** hypothesis).

MULTIPLE CHOICE QUESTIONS

1. The branch Genetics started in:
   (a) 1857 (b) 1866
   (c) 1900 (d) 1905
2. Sum total of characters which are transmitted from generation to generation constitute:
   (a) Genetics (b) Phenocopy
   (c) Heredity (d) Variations
3. Rediscovery of Mendel's work was made in:
   (a) 1866 (b) 1900
   (c) 1898 (d) None of these
4. The term Genetics was first used by:
   (a) Johannsen (b) Punnett
   (c) Bateson (d) Darlington
5. Genetics deals with: (AFMC 2001)
   (a) Genes (b) Heredity
   (c) Variations (d) Heredity and variations
6. The hereditary variations are due to:
   (a) Asexual reproduction (b) Sexual reproduction
   (c) Vegetative reproduction (d) All of these
7. Concept of 'Pangenes' was given by:
   (a) Wolff (b) Swammerdam
   (c) Johannsen (d) Darwin
8. 'Genotype-phenotype concept' was given by:
   (a) Johannsen (b) Charles Darwin
   (c) Mendel (d) Bateson
9. When two genotypes produce the same phenotype due to different environments one is called .... of other:
   (a) Phenotype (b) Allelomorph
   (c) Phenocopy (d) None of these
10. Mendel worked on:
    (a) Pigeon pea (b) Garden pea
    (c) Sweet pea (d) Chick pea
11. Mendel originally belonged to:
    (a) Sweden (b) Austria
    (c) Australia (d) Czechoslovakia
12. Mendel published the results of his experiments in:
    (a) 1857 (b) 1866
    (c) 1868 (d) 1900
13. Mendel studied how many pairs of contrasting characters?
    (a) 1 (b) 2
    (c) 7 (d) 10
14. Which of the following characters was not studied by Mendel?
    (a) Plant height (b) Position of flower
    (c) Colour of pod (d) Length of pod
15. The term 'Allele' was proposed by:
    (a) Johannsen (b) Bateson
    (c) Mendel (d) Punnett
16. Emasculation is achieved by:
    (a) Removal of stigma
    (b) Removal of anthers
    (c) Removal of sepals and petals
    (d) All of the above
17. Alleles are:
    (a) Homologous chromosomes
    (b) Linked genes
    (c) Dominant genes
    (d) Alternate forms of gene
18. If a plant heterozygous for tallness is selfed, the F_2 generation has both tall and dwarf plants. This proves the principle of:
    (a) Dominance (b) Segregation
    (c) Independent assortment (d) Incomplete dominance
19. In an experiment on pea, plants with yellow round seeds were crossed with plants with green wrinkled seeds; the phenotypic ratio of F_1 progeny is: (MPPMT 2002)
    (a) 9 yellow round : 3 round green : 3 wrinkled yellow : 1 green wrinkled
    (b) All wrinkled green
    (c) All yellow round
    (d) 1 YR : 1 GR : 1 YW : 1 GW
20. Red (RR) flower plant is crossed with white (WW), all the offsprings are pink, this indicates that R gene is:
    (a) Hybrid (b) Recessive
    (c) Incomplete dominant (d) Mutant
21. Cross between a heterozygous individual and homozygous recessive parent is called: (CET Karnataka 2000; CET MH 2003)
    (a) Monohybrid cross (b) Dihybrid cross
    (c) Back cross (d) Test cross
22. An organism with two identical alleles of gene in a cell is:
    (a) Dominant (b) Homozygous
    (c) Heterozygous (d) Recessive
23. In F_2 progeny of dihybrid cross, the expected genotypic proportions of individuals homozygous for both dominant characters is:
    (a) 3/16 (b) 9/16
    (c) 12/16 (d) 1/16
24. Mendel performed his work on pea plants during:
    (a) 17th century (b) 18th century
    (c) 19th century (d) 20th century
25. Who is known as 'father of Genetics'?
    (a) C. Darwin (b) G. Mendel (c) de Vries (d) Weismann
26. Theory of 'Continuity of Germplasm' was put forward by: (CPMT 2000)
    (a) Bateson (b) de Vries
    (c) Darwin (d) Weismann
27. One complete set of chromosomes inherited as a unit from one parent is known as:
    (a) Genotype (b) Genome
    (c) Gene pool (d) Karyotype
28. The geometrical device that helps in visualizing all the possible combinations of male and female gametes is known as:
    (a) Bateson square (b) Morgan square
    (c) Punnett square (d) Mendel square

*29. The condition in which only one allele of a pair is present is called:
(a) Homozygous (b) Hemizygous
(c) Heterozygous (d) Incomplete dominance

*30. A pure tall pea plant was reared in soil poor in the nutrition and reached the size of a pure dwarf pea plant, if this plant is selfed, then the genotype in the F_1 gen. is most likely to be:
(a) All tall (b) 50% tall : 50% dwarf
(c) All dwarf (d) Not possible to predict

31. A cross between a plant heterozygous for two factors and a plant recessive for both the factors, gives a phenotypic ratio of: (CET Karnataka 2000)
(a) 9 : 1 : 1 : 7 (b) 9 : 3 : 3 : 1
(c) 1 : 1 : 1 : 1 (d) 1 : 7 : 7 : 1

32. Which is back cross in a monohybrid cross?
(a) 9 : 3 : 3 : 1 (b) 1 : 1
(c) 1 : 2 : 1 (d) 3 : 1

33. Which term represents a pair of contrasting character?
(a) Homozygous (b) Heterozygous
(c) Complementary genes (d) Allelomorphs

34. In Monohybrid cross, the F_2 phenotypic ratio is:
(a) 1 : 2 : 1 (b) 2 : 1
(c) 3 : 1 (d) 1 : 3 : 1

35. The term heterosis represents:
(a) Hybrid incompatibility (b) Hybrid vigour
(c) Hybrid sterility (d) Structural hybridity

36. Genes which in homozygous condition result in non-viable progeny are:
(a) Duplicate genes (b) Linked genes
(c) Lethal genes (d) Epistatic genes

37. Which is called a 'pleiotropic gene'? (AFMC 2001)
(a) Control characters of human beings only
(b) Control a character of plants
(c) Control one character in association with other
(d) Control more than one character

38. The genotype of a dominant parent is determined by crossing it with a hybrid; this cross is called:
(a) Back cross (b) Test cross
(c) Long cross (d) Red cross

39. Allosomes are:
(a) Bead like structures in chromosomes
(b) Node like structures on chromosomes
(c) Sex-chromosomes
(d) None of the above

40. 'F_1' generation represents:
(a) First fertile generation
(b) First final generation
(c) First filial generation
(d) First federation generation

41. Monohybrid test cross ratio is:
(a) 1 : 2 : 1 (b) 3 : 1
(c) 1 : 1 (d) 2 : 1

42. Incomplete dominance was first reported in 4 o'clock plant by:
(a) Mendel (b) Morgan
(c) Bateson (d) Correns

43. Same genotypic and phenotypic ratios in F_2 generation are obtained in: (DPMT 2001)
(a) Complete dominance (b) Blending inheritance
(c) Codominance (d) None of these

44. In which, incomplete dominance is seen? (MPPMT 2001)
(a) Wheat (b) Maize
(c) Mouse (d) Snapdragons

45. Lethal factors were reported in plants by:
(a) Cuenot (b) Baur
(c) Bateson (d) Morgan

46. Intraallelic gene suppression is called:
(a) Epistatis (b) Hypostatis
(c) Dominance (d) None of these

47. Gene interaction in which either of dominant gene is enough to give rise to same phenotypic effect is:
(a) Complementary gene (b) Duplicate gene
(c) Epistatic gene (d) Supplementary gene

48. When two pairs of genes interact to give 9 : 7 F_2 ratio, they are: (CBSE 2001)
(a) Supplementary factors (b) Complementary factors
(c) Epistatic factors (d) Duplicate factors

49. 12 : 3 : 1, F_2 ratio is obtained in interaction of .... factors:
(a) Complementary (b) Supplementary
(c) Epistatic (d) Inhibitory

50. Mendel may not be able to establish the law of independent assortment, if both characters were located on:
(a) Separate non-homologous chromosomes
(b) Same homologous chromosomes
(c) Separate chromosome but at different loci
(d) Sex chromosomes

51. Exception to Mendel's law of Independent assortment was first discovered by:
(a) Morgan (b) Sturtevant
~~(c) Bateson and Punnet~~ (d) None of these

52. Phenomenon of linkage was first discovered in: (MPPMT 2000)
(a) Sweet pea (b) Garden pea
(c) *Mirabilis* (d) Snapdragon

53. Who coined the term linkage?
(a) Bateson and Punnet (b) T.H. Morgan
(c) Correns (d) de Vries

54. Coupling and repulsion phenomena are concerned with:
(a) Crossing over (b) Linkage
(c) Mutation (d) None of these

55. Theory of linear arrangement of genes on chromosomes was formulated by:
(a) Sturtevant (b) Morgan
(c) Bateson (d) Mendel

56. When blue flower long pollen plant (BBLL) was crossed with red flowered round pollen plant (bbll) in *Lathyrus* and their F_1 was crossed with red round parent, then what is the ratio of blue long and red round obtained in this cross?
(a) 1/16 : 1/16 (b) 7/16 : 7/16
(c) 7/16 : 1/16 (d) 9/16 : 3/16

*57. How many linkage groups are present in cyanophyceae?
(a) 2 (b) 1
(c) 4 (d) 0

58. If 2n = 20 in a plant, then how many linkage groups are present is this?
(a) 20 (b) 10
(c) 5 (d) 5 or 10

59. Somatic crossing over was discovered in *Drosophila* by:
(a) Pontecorvo (b) Morgan
(c) Stern (d) Serebrousky

60. G. Pontecorvo observed non-germinal cover in:
(a) Maize (b) *Drosophila*
(c) *Aspergillus* (d) None of these

61. Most accepted theory of crossing over is:
(a) Copy choice theory (b) Precosity theory
(c) Contact first theory (d) Breakage first theory

62. Crossing over is more frequent in:
(a) Males (b) Females
(c) Equal in both (d) None of these

63. Bar eye character in *Drosophila* is due to:
(a) Deficiency (b) Duplication
(c) Translocation (d) Polyploidy

64. Exchange of chromosomal segments between non-homologous chromosomes is:
(a) Crossing over (b) Inversion
(c) Translocation (d) None of these

65. Which is called 'illegitimate crossing over'?
(a) Inversion (b) Translocation
(c) Transposons (d) None of these

66. The process which involves reverse order of genes in chromosome is:
(a) Deficiency (b) Aneuploidy
(c) Inversion (d) Translocation

67. '*x*' represents:
(a) Gametic number
(b) Basic chromosome number
(c) Haploid number
(d) All of the above

68. Presence of chromosome number, which is different from the multiple of basic chromosome no. is called?
(a) Hyperploidy (b) Heteroploidy
(c) Aneuploidy (d) Euploidy

69. $2n - 2$ is a:
(a) Monosomic (b) Nullisomic
(c) Tetrasomic (d) Trisomic

70. If haploid chromosome no. in an organism is 12, what is the chromosome no. present in its trisomic?
(a) 11 (b) 13
(c) 25 (d) 23

71. Trisomics were first obtained in:
(a) Chinese spring wheat (b) Pigweed
(c) Jimson weed (d) Maize

72. Reduction in size of vegetative and floral parts is found in:
(a) Autopolyploids (b) Allopolyploids
(c) Haploids (d) Diploids

73. 'Gigantism' is mostly found in:
(a) Autopolyploids (b) Allopolyploids
(c) Haploids (d) None of these

74. Polyploidy can be artificially induced by: (CPMT 2000)
(a) 0.1 M NaCl solution (b) 0.25 M sucrose solution
(c) Zeatin (d) Colchicine

75. Colchicine is used in what concentration for arresting and breaking the spindle?
(a) 1–5% (b) 0.1–0.5%
(c) 0.01–0.5% (d) Any concentration

76. Colchicine was first obtained from *Colchicum autumnale* by:
(a) Dustin (b) Houde
(c) E.R. Sears (d) Blakeslee

77. Colchicine is a:
(a) Steroid (b) Alkaloid
(c) Cholesterol (d) None of these

78. Natural autopolyploidy is found in:
(a) Cynodon (b) Grapes
(c) Watermelon (d) All of these

79. More the distance between the two genes on a chromosome:
(a) More is the linkage strength
(b) Lesser is the linkage strength
(c) Linkage strength remains unchanged
(d) None of the above

*80. Complete linkage is observed in:
(a) ♂ *Drosophila* (b) ♀ *Drosophila*
(c) Birds (d) Maize

81. Percentage of crossing over will be more if:
(a) Linked genes are located far away from each other
(b) Linked genes are located close to each other
(c) Both (a) and (b)
(d) None of the above

82. *Raphanobrassica* is a classical example of:
(a) Autopolyploidy (b) Allopolyploidy
(c) Segmental polyploidy (d) None of these

83. Who is associated with *Raphanobrassica*?
(a) Muntzing (b) E.R. Sears
(c) Karpechenko (d) None of these

84. 'Triticale' is derived from cross between?
(a) Wheat and aegilops (b) Wheat and rice
(c) Wheat and maize (d) Wheat and rye

85. Which is hexaploid sps. of wheat? (MPPMT 2002)
(a) *Triticum durum* (b) *T. monococcum*
(c) *T. aestivum* (d) *T. turgidum*

86. In common hexaploid bread wheat, the three diploid genomes are:
(a) A, B and C (b) A, C and D
(c) B, C and D (d) A, B and D

87. The three genomes of common hexaploid wheat show:
(a) Homologous relationship
(b) Non-homologous relationship
(c) Homoeologous relationship
(d) None of the above

88. Mutation is:
(a) Change that is inherited
(b) Change in parents not inherited
(c) Plant growth controlling factor
(d) Change which affects the offsprings of F_2 gen.

89. Mutation was first discovered in:
(a) *Drosophila* (b) *Neurospora*
(c) *E. coli* (d) *Oenothera*

90. The term 'Sports' was given by:
(a) Hugo de Vries (b) Darwin
(c) Lamarck (d) None of these

91. The changes due to structural changes in chromosomes:
(a) Can be reversed (b) Cannot be reversed
(c) Is not known (d) None of these

92. Earliest record of point mutation goes back to:
(a) 1691 (b) 1791
(c) 1910 (d) 1940

93. Which of the following is called *Drosophila* of plant kingdom?
(a) *E. coli* (b) *Acetabularia*
(c) *Neurospora* (d) *Saccharomyces*

94. Suppression of action of genes by genes not allelomorphic to those suppressed is called:
(a) Dominance (b) Episome
(c) Codominance (d) Epistasis

95. A mutation in sheep called 'Ancon sheep' was recorded by:
(a) de Vries (b) Darwin
(c) Seth Wright (d) None of these

96. Mutagen is:
(a) Organism in which mutation has occurred
(b) Mutation inducing agent
(c) Both (a) and (b)
(d) None of the above

97. Frequency of mutation:
(a) Varies with character and organism
(b) Can be increased by X-rays
(c) Is greatly affected by environmental factors
(d) All of the above

98. A cross between unlike organisms is called:
(a) Test cross (b) Heterosis
(c) Back cross (d) Hybrid

99. Which is point of mutation in a cell?
(a) Nucleus (b) Chromosome
(c) Centromere (d) Gene

100. In nature, the rate of mutation is:
(a) 1×10^5 (b) 1×10^8
(c) 1×10^{-5} (d) 1×10^{12}

101. Mutations are:
(a) Mostly useful (b) Always useful
(c) Rarely useful (d) Always harmful

102. Who used X-rays to cause mutation?
(a) Morgan (b) Muller
(c) Alterberg (d) Auerbach

103. Most of mutations are:
(a) Forward (b) Reverse directional
(c) Directionless (d) None of these

104. Changes due to mutation are:
(a) Small (b) Negligible
(c) Large (d) All of these

105. Pseudodominance is:
(a) There is incomplete dominance
(b) Dominance of recessive alleles in a single generation
(c) Deficiency in which a recessive allele will behave like a dominant allele
(d) There is no such phenomenon

106. Which one of the following support the idea that mutational changes have been more frequent at the time when living cells first evolved?
(a) Early cells do not have DNA, which is a stable compound and hence changes were frequent
(b) More O_3 was frequent in primitive earth's atmosphere thus permitting more radiation
(c) Less O_3 was present thus permitting more radiation to penetrate earth's atmosphere
(d) Early cells reproduced asexually and hence mutations occurred

107. Induced mutations are most common in:
(a) Millets
(b) Lentils
(c) Vegetatively propagated plants
(d) Cereals

108. If an organism is having genotype AaBb, then what are the possible combinations of gametes after meiosis?
(a) AB, ab (b) Aa, Bb
(c) AB, aB, Ab, ab (d) Not possible to tell

109. Suppose DNA has base sequence as UAC, GAC, AGC, CGC, ACA, AAA and due to mutation only first base is deleted, what is the effect on coding?
(a) First amino acid will be different
(b) There will be one amino acid less
(c) Complete change in type and sequence of amino acids
(d) No change

110. Which of the following mutagens can be best used in inducing mutation in micro-organisms?
(a) X-rays (b) β-rays
(c) UV-rays (d) γ-rays

111. Which of the following is non-ionizing radiation?
(a) X-rays (b) β-rays
(c) γ-rays (d) UV-rays

112. Auxotrophs in *Neurospora* were produced by which radiation by Beadle and Tatum?
(a) γ-rays (b) α-rays
(c) UV-rays (d) IR-rays

113. UV-rays as mutagenic agents were shown by :
(a) Auerbach (b) Stadler
(c) Altenberg (d) Muller

114. Chemicals as mutagenic agents were first shown by:
(a) Altenberg (b) Auerbach
(c) Stadler (d) None of these

115. Which is the most widely used chemical mutagen in plant mutation breeding nowadays?
(a) Mustard gas (b) EMS
(c) MMS (d) Nitrous acid

116. Who is associated with **'Green Revolution'** in India?
(a) E.J. Butler (b) M.S. Swaminathan
(c) R.S. Paroda (d) B.P. Pal

117. Which of the following is an achievement of mutations?
(a) Todd's Mitcham var. (b) Aruna var.
(c) Sharbati sonora var. (d) All of these

118. Base substitutions caused by 5-bromo uracil and BudR are called:
(a) Inversions (b) Transitions
(c) Transversions (d) Translocations

119. Which type of mutations is more frequent?
(a) Transitions (b) Transversions
(c) Both equal (d) Not known

120. Proflavin and Acridine orange induce:
(a) Transitions (b) Transversions
(c) Inversions (d) Frameshift mutations

121. Which is not associated with mutations?
(a) Better progenies
(b) Death of organisms
(c) Change in genetic constitution
(d) Hybrid vigour

122. 'Mutations which are recessive are not lost by a gene pool' is called:
(a) Survival of dominant (b) Survival of recessive
(c) Hardy Weinberg law (d) None of these

123. Cytoplasmic inheritance is responsible for:
(a) Inheritance of kappa particles
(b) Iojap inheritance in corn
(c) Petite character in yeast
(d) All of the above

*124. Cytoplasmic male sterility in maize is inherited:
(a) Paternally (b) Maternally
(c) Both (a) and (b) (d) None of these

125. Who is credited to have differentiated between heritable variation and environmental variation?
(a) Darwin (b) Morgan
(c) de Vries (d) Bateson

126. The resistance developed by some insects against insecticides is due to:
(a) Hybrid vigour
(b) Genetic mutations
(c) Variations due to sexual rep.
(d) Genetic recombinations

127. Who coined the term Heterosis?
(a) Mendel (b) G.H. Shull
(c) Schmidt (d) Schleiden

128. A dwarf pea plant was treated with GA3, it grew as pure tall plant. If it is crossed with a pure tall plant, then phenotypic ratio of F_1 is likely to be:
(a) All dwarf (b) 50% tall, 50% dwarf
(c) 75% tall, 25% dwarf (d) All tall

129. Which of the following crosses would result in 1 : 2 : 1 F_2 ratio?
(a) Yg × gg (b) Yg × yg
(c) Yg × yy (d) YY × gg

130. 'Gene Battery Model' was given by:
(a) Jacob and Monod
(b) McClintock and Creighten
(c) Bawden and Pierre
(d) Bridden and Davidson

131. The first 'hybrid' was produced by:
(a) Camerarius (b) Fairchild
(c) Lamarck (d) N. Grew

132. Sex determination was first of all studied in which plant?
(a) *Coccinia* (b) *Melandrium*
(c) *Rumex* (d) *Humulus*

133. Which of the following shows slowest cell division?
(a) Haploid (b) Diploid
(c) Polyploid (d) Same in all

134. $2n = x = 7$, represents a:
(a) Haploid (b) Diploid
(c) Monoploid (d) Polyploid

135. In wheat $2n = 6x = 42$. No. of possible monosomics is:
(a) 42 (b) 21
(c) 7 (d) 6

136. Translocation was first reported in:
(a) Datura (b) Maize
(c) Oenothera (d) Doob grass

137. In snapdragon, when yellow leaved var. (Aurea) × Aurea, what is the ratio of yellow : green in progeny?
(a) 3 : 1 (b) 9 : 3
(c) 1 : 1 (d) 2 : 1

138. Mutations are mostly:
(a) Dominant (b) Incompletely dominant
(c) Codominant (d) Recessive

139. Suppose DNA has base sequence AAG GAG GAC CAA CCA, which one represents frameshift mutations?
(a) AAG GAG GAC CAA CCA
(b) AAG AAG GAC CAA CCA
(c) AAG GAG ACC AAC CAA
(d) AAG GAG GAC CAA CCA

140. No. of linkage groups is equal to:
(a) Diploid no. of chromosomes
(b) Haploid no. of chromosomes
(c) Tetraploid no. of chromosomes
(d) None of the above

141. Who discovered Mendel's principle in 1900 A.D.?
(a) Avery, McLeod, McCarty
(b) Sutton, Morgan and Bridges
(c) Bateson, Punnett and Bridges
(d) de Vries, Correns and Tschermak

*142. Heterosis is also called: (BHU 1999)
(a) Hybrid vigour (b) Hybrid sterility
(c) Mutation (d) Variation

143. Why are haploids superior to diploids in study of mutations?
(a) They have shorter life time
(b) Smaller no. of chromosomes
(c) They allow expression of recessive mutation immediately
(d) Obtained in large number

144. The individuals having same maternal and paternal parents are called?
(a) Epistasis (b) Hypostasis
(c) Siblings (d) Gynander

145. When a pyrimidine is replaced by purine, it is called: (AIIMS 2002)
(a) Frameshift mutation (b) Transition
(c) Transversion (d) Reversible mutation

146. It is easier to study polygenic inheritance of characters in plants than in animals because in the former:
(a) Mating can be controlled
(b) Mating cannot be controlled and a small number of progeny is produced
(c) Mating can be controlled and a large number of progeny is produced
(d) Small number of progeny is produced

***147.** The recessive gene that always produces its effect is:
(a) Pleiotropic gene (b) Complementary gene
(c) Holandric gene (d) Supplementary gene

148. First exception of Mendel's law of independent assortment was given by:
(a) T.H. Morgan (b) Correns
(c) Bateson and Punnett (d) Hugo de Vries

149. In polygenic inheritance, the parents fall into two distinct classes but the F_1 generation shows intermediate characters because of:
(a) Dilution of dominant gene
(b) Dilution of recessive gene
(c) Excess of recessive gene
(d) None of the above

150. Mendel's law of segregation is based on the fact that genes are located on chromosomes and that:
(a) Analogous chromosomes pair and segregate
(b) Homologous chromosomes pair and segregate
(c) No crossing over takes place between homologous chromosomes
(d) None of the above

151. Which one is a sex-linked disease?
(a) Beri Beri (b) Tylosis
(c) Albinism (d) Colour blindness

152. The number of linkage groups depends upon the:
(a) Length of chromosomes
(b) Total number of chromosomes
(c) Haploid number of chromosomes
(d) None of the above

153. The first animal for which a linkage map was constructed was:
(a) *Drosophila* (b) Rat
(c) *Neurospora* (d) *Pisum sativum*

154. During crossing over, genes and chromosomes are re-assorted as a result of exchange of parts of chromatids between:
(a) Heterologous chromosomes
(b) Homozygous chromosomes
(c) Sex chromosomes
(d) Homologous chromosomes

155. In *Paramoecium aurelia*, some strains are 'killers' due to the presence of:
(a) Ribosomal particles (b) Kappa particles
(c) Vegetative particles (d) Petite colonies

156. The crossing over of genes occurs in 50% of the cases of a hybrid AaBb. Which of the following set of gametes may be formed?
(a) Aa = 50% Bb = 50%
(b) ab = 25% AB = 75%
(c) AB = 25% aB = 25%; Ab = 25% aB = 25%
(d) AB = 50% ab = 50%

157. A cross between red-flowered and white-flowered plants results in pink-flowered plants in F_1; when the F_1 hybrids were self-fertilised, the resulting F_2 generation revealed 1 red : 2 Pink : 1 white progeny. This type of inheritance is the result of:
(a) Incomplete dominance (b) Co-dominance
(c) Pleiotropic genes (d) Complementary genes

158. Which one of the following traits was not studied by Mendel?
(a) Seed colour (b) Flower colour
(c) Flower position (d) Seed size

159. Which of the following conditions represents a case of co-dominant genes?
(a) A gene expresses itself, suppressing the phenotypic effect of its alleles
(b) Genes that are similar in phenotypic effect when present separately, but when together interact to produce a different trait
(c) Alleles, both of which interact to produce a trait, which may or may not resemble either of the parental types
(d) Alleles, each of which produces an independent effect in a heterozygous condition

160. If the frequency of a recessive phenotype in a stable population is 25%, the frequency of the dominant allele in that population is:
(a) 50% (b) 40%
(c) 25% (d) 10%

161. Genetic mutation changes the heritable phenotypic characters by altering:
(a) The sequence of amino acids of proteins formed in the parents
(b) The sequence of the RNA in the cytoplasm
(c) The somatic characters of the parents
(d) The sequence of the templates of RNA synthesis

162. The marriage between blood relations and cousins should be prohibited because:
(a) It reduces the reproductivity
(b) It will not prove successful
(c) It increases the probability of increasing the transmission of defective germplasm
(d) None of the above

163. Frameshift mutation means:
(a) Shifting of a block of genes from its position
(b) Change in the exact number of chromosomes
(c) Change in chemical nature of gene
(d) Increase or decrease in the number of chromosomes

164. Genic balance theory of sex determination was given by: **(MPPMT 1997)**
(a) Mendel (b) Morgan (c) Bridges (d) Devlin.

165. Mutation is essential for evolution because:
(a) It produces new variations
(b) It stops the struggle for existence
(c) It causes recombination
(d) It brings a balance in the environment

166. *Neurospora* is suitable for genetic studies because:
(a) Its vegetative phase is also diploid
(b) It can be cultured in defined media in the laboratory and it has a very short life cycle
(c) It has a long life cycle and it can also be cultured in a culture media
(d) None of the above

167. Johannsen coined the term:
(a) Genotype (b) Gene
(c) Phenotype (d) All of these

168. Sometimes a gene masks the expression of another gene at a different locus. This phenomenon is known as:
(a) Incomplete dominance (b) Co-dominance
(c) Epistasis (d) None of these

169. The science which deals with the application of the principles of heredity to the improvement of mankind is:
(a) Cell biology (b) Eugenesis
(c) Plant genetics (d) Cytogenesis

170. The characters that appear in the first generation are called:
(a) Dominant characters
(b) Recessive characters
(c) Both recessive and blend characters
(d) None of the above

171. Test cross of a trihybrid will yield a ratio of:
(a) 27 : 9 : 9 : 9 : 3 : 3 : 3 : 1
(b) 1 : 1 : 1 : 1 : 1 : 1 : 1 : 1
(c) 9 : 9 : 3 : 3 : 3 : 1 : 1 : 1
(d) None of the above

172. Mutations which alter nucleotide sequence within a gene are:
(a) Frameshift mutations (b) Base pair substitutions
(c) Both (a) and (b) (d) None of these

173. Unit of measurement of the radiations in terms of an ionisation unit is:
(a) Roentgen (b) Gray
(c) Rads (d) All of these

174. The scientist who performed some significant experiments on the evening primrose, *Oenothera lamarkiana* is: (St. Jones 2002)
(a) Charles Darwin (b) Gregor Mendel
(c) Hugo de Vries (d) August Weismann

175. The phenotypic ratio of a trihybrid cross will be:
(a) 27 : 9 : 9 : 9 : 3 : 3 : 3 : 1
(b) 28 : 9 : 9 : 3 : 3 : 3 : 1
(c) 4 : 9 : 20 : 4
(d) 27 : 9 : 8 : 3 : 3 : 3 : 1 : 1

176. The distance between the gene is measured by:
(a) Locus (b) Map units
(c) Both (a) and (b) (d) None of these

177. When the dominant allele of one locus and the recessive allele of the other occupy the same chromosome the linkage is said to be in:
(a) Coupling phase (b) Repulsion phase
(c) Both (a) and (b) (d) None of these

*178. Who among the following are known for their work on plant breeding in India?
(a) M.S. Swaminathan and B.P. Pal
(b) M.S. Swaminathan, B.P. Pal and N.E. Borlaug
(c) G.A. Gani, B.S. Kadam and N.E. Borlaug
(d) M.S. Swaminathan and N.E. Borlaug

179. Phenocopies have:
(a) Different phenotypes (b) Same genotypes
(c) Different genotypes (d) None of these

180. If the diploid set of chromosomes of one species is AA and of the other is BB, the chromosomal constitution of the hybrid will be AB, the duplication of which will give rise to an:
(a) Allotetraploid (AABB) (b) Autotetraploid (AABB)
(c) Autotriploid (AAB) (d) Allotetraploid (AAAA)

*181. Plants can be made resistant to disease by:
(a) Mutation
(b) Increasing the chromosome numbers
(c) Breeding with their wild relatives
(d) Colchicine

182. How many linkage groups of chromosomes will be present in case of maize, if all its genes are mapped? (Maize has 10 pairs of chromosomes)?
(a) 4 (b) 20
(c) 10 (d) 5

183. Euploidy is best explained by: (BHU 1998)
(a) One chromosome less than the haploid set
(b) One chromosome more than the haploid set
(c) One chromosome more than the diploid set
(d) Exact multiples of a haploid set of chromosomes

184. The slow process by which new types of organisms arise from existing forms by genetic variation is called:
(a) Genetics (b) Evolution
(c) Plant improvement (d) Polyploidy

185. When a chromosome with genes in the order of ABCDEFG may change to AEDCBFG, this arrangement occurs due to the phenomenon of:
(a) Deletion (b) Translocation
(c) Addition (d) Inversion

186. From a cross AABb × aaBb, the genotypes AaBB : AaBb : Aabb : aabb will be obtained in the following ratio: (BHU 1994)
(a) 1 : 1 : 1 : 1 (b) 1 : 2 : 1 : 0
(c) 1 : 3 : 1 : 0 (d) 1 : 1 : 1 : 0

*187. The genes controlling seven traits in pea studied by Mendel were later found to be located on the following number of chromosomes: (BHU 1994)
(a) Seven (b) Four
(c) Five (d) Six

188. *Datura* is a classical example of a: (BHU 1993)
(a) Trisomic (b) Triploid
(c) Monosomic (d) Monoploid

189. In case of incomplete dominance in F_2 generation: (BHU 1995)
(a) Genotypic ratio is 3 : 1
(b) Phenotypic ratio is 3 : 1
(c) Genotypic ratio = phenotypic ratio
(d) Nothing can be concluded

190. Linkage is the phenomenon of close association of genes to remain together on a chromosome was first proved by: (BHU 1997)

(a) Boveri
(b) Crick
(c) Temin and Baltimore
(d) None of these

191. The genotype of the F_1 heterozygous tall plants is:
(a) Tt
(b) tt
(c) TT
(d) None of these

192. Mendel's principle of segregation was based on the separation of alleles in the garden pea during: (MPPMT 1993)
(a) Embryonic development
(b) Seed formation
(c) Gamete formation
(d) Pollination

193. The percentage of 'ab' gametes produced by 'AaBb' parent will be:
(a) 25
(b) 50
(c) 75
(d) 12.5

194. A maize plant differs from wheat because of: (CPMT 1992)
(a) RNA
(b) DNA
(c) Genotype
(d) Phenotype

195. A cross between an F_1 hybrid and a recessive parent gives the ratio of: (MPPMT 1992)
(a) 3 : 1
(b) 1 : 1
(c) 2 : 1
(d) 4 : 1

196. The main cause for the discovery of laws of heredity by Mendel: (CPMT 1992)
(a) He analysed every trait independently
(b) He was lucky that he did not come across linkage
(c) His plants were true breeding
(d) All of the above

197. The product of hybridization is known as:-(MPPMT 1993)
(a) Clone
(b) Homozygous
(c) Hybrid
(d) Heterozygous

198. A red flowered plant when crossed with white flowered plant it gave a majority of red flowered plants in F_1 generation. The genes for red colour is considered as: (CPMT 1992)
(a) Recessive
(b) Assorted
(c) Sex-linked
(d) Dominant

199. The phenomenon in which an allele of one gene suppresses the activity of an allele of another gene is known as: (CBSE 1995)
(a) Dominance
(b) Inactivation
(c) Epistasis
(d) Suppression

200. Alleles of different genes that are on the same chromosome may occasionally be separated by a phenomenon known as: (MPPMT 1993)
(a) Pleotropy
(b) Epistasis
(c) Continuous variation
(d) Crossing over

*201. According to Bateson and Punnett, the correct sequence is: (CBSE 1990)

	Coupling	**Repulsion**
(a)	AABB × aabb	AAbb × aaBB
(b)	AABB × aabb	AABB × aabb
(c)	AABB × aabb	AAbb × aabb
(d)	AAbb × aaBB	AAbb × aabb

202. The phenomenon of linkage was first observed in the plant: (MPPMT 1993)
(a) *Lathyrus odoratus*
(b) *Pisum sativum*
(c) *Oenothera lamarckiana*
(d) *Datura metel*

203. Which one of the following phenomena of hereditary characters was not known to Mendel? (CPMT 1990)
(a) Assortment according to probability
(b) Independent assortment
(c) Dominant and recessive traits
(d) Linkage

204. Maize was used as an experimental material in crossing experiments to establish linkage relationship between genes by:
(a) Hutchinson
(b) Bateson and Punnett
(c) Bridges
(d) Morgan

205. If the linkage was known at the time of Mendel, then which of the following laws Mendel was unable to explain?
(a) Law of dominance
(b) Law of independent assortment
(c) Law of segregation
(d) Law of purity of gametes

206. Turner's syndrome is due to:
(a) Monosomic chromosomes
(b) Polysomic chromosomes
(c) Trisomic chromosomes
(d) Bisomic chromosomes

207. An abnormal human male phenotype involving an extra X chromosome (XXY) is a case of: (CBSE 1995)
(a) Down syndrome
(b) Intersex
(c) Edward syndrome
(d) Klinefelter syndrome

208. XO chromosomes abnormality cause: (CPMT 1992)
(a) Down syndrome
(b) Turner's syndrome
(c) Criminal syndrome
(d) Klinefelter's syndrome

209. Type of gene mutation involving a change from purine to purine or pyrimidine to pyrimidine:
(a) Transversion
(b) Inversion
(c) Transduction
(d) Transition

210. When chromosome sets are present in multiples of '*n*', the condition is called as:
(a) Polyploidy
(b) Aneuploidy
(c) Euploidy
(d) Diploidy

211. Smallest unit of genetic material which when mutated produces a phenotypic effect is: (AFMC 1992)
(a) Recon
(b) Gene
(c) Muton
(d) Nucleic acid

212. Which of the following is a strong chemical mutagen? (MPPMT 1991)
(a) Methane
(b) Guanine
(c) Carbon tetrasulphide
(d) Caffeine

213. Transversion is:
(a) Replacement of adenine with guanine
(b) Replacement of purine with purine
(c) Replacement of purine with Pyrimidine and *vice-versa*
(d) Addition of bases to the pre-existing chain

214. The ultimate source of variations during evolution is:
(a) Mutations
(b) Sexual reproduction
(c) Genetic recombination
(d) Migration of populations into new areas

215. Mutation is:
(a) A change that is inherited
(b) A change that affects the parents only but never inherited

(c) A factor responsible for plant growth
(d) A change that affects the offsprings of F_2 generation only

216. Which of the following is physical mutagen?
(a) X-ray (b) α-ray
(c) γ-ray (d) β-ray

217. If the DNA codons are ATG ATG ATG and a cytosine base is inserted at the beginning, which of the following will result? (CBSE 1995)
(a) A non-sense mutation (b) CA TGA TGA TG
(c) CAT GAT GAT G (d) CATG ATG ATG

218. *Triticum aestivum* wheat is: (MPPMT 1993, 2000)
(a) Haploid (b) Diploid
(c) Tetraploid (d) Hexaploid

219. The plant which became famous due to theory of mutation: (CPMT 1992)
(a) *Triticum vulgare* (b) *Oenothera lamarckiana*
(c) *Pisum sativum* (d) *Primula sinensis*

220. Why do we choose the haploid cells for mutations? (CBSE 1990)
(a) Haploid cell can be vegetatively propagated in large numbers
(b) Mutations are recessive, thus, haploid cells give immediate results completely
(c) Mutations are dominant, thus, haploid cells give better results
(d) Haploid cells are easily produced through either mitosis or meiosis

221. de Vries proposed:
(a) Theory of spontaneous generation
(b) Theory of mutation
(c) Theory of natural selection
(d) Theory of speciation

222. Chromosome complement with $2n - 1$ is called as: (BHU 1998)
(a) Trisomy (b) Nullisomy
(c) Tetrasomy (d) Monosomy

223. Mutation is the change in: (BHU 1998)
(a) Gene frequency
(b) Base pairs in the DNA molecule
(c) Genetic drift
(d) Environmental mechanism of evolution

224. The gene pool of population tends to remain stable if certain conditions are met. These conditions include large populations, no mutation, no migration and:
(a) Natural selection
(b) Random mating
(c) Reduction of predators
(d) Moderate environmental changes

225. Alleles that produce independent effects in heterozygous condition are called: (CBSE 1996)
(a) Supplementary alleles (b) Co-dominant alleles
(c) Epistatic alleles (d) Complementary alleles

226. The presence of continuous phenotypic variation in an F_1 generation suggests that a character is inherited by: (AIIMS 1994)
(a) Epistasis (b) Recombination
(c) Polygenic inheritance (d) Gene linkage

227. Colchicine is employed to diploidize haploid cells by: (CBSE 1996)
(a) Inhibiting formation of mitotic spindle
(b) Allowing replication of DNA twice in one cell cycle
(c) Inhibiting formation of centromere
(d) Inhibiting mitosis

228. A man with a certain disease marries a normal woman. They have 8 children (3 daughters and 5 sons). All the daughters suffer from their father's disease but none of the sons are affected. Which of the following mode of inheritance do you suggest for this disease? (CBSE 1996)
(a) Sex-linked dominant (b) Sex-limited recessive
(c) Sex-linked recessive (d) Autosomal dominant

229. Hybrid vigour is mostly due to: (EAMCET 1998)
(a) Heterozygosity
(b) Homozygosity of pure characters
(c) Mixing up of cytoplasm of the male with that of female exclusively
(d) Superiority of all the genes

230. H.J. Muller was awarded the Nobel Prize for this: (CBSE 1996)
(a) Discovery that ionizing radiations can induce gene mutation
(b) Work on gene mapping in *Drosophila*
(c) Efforts to prevent the use of nuclear weapons
(d) Discovery that chemicals can induce gene mutation

231. A child is born with extra chromosome in each of its cells. This condition is usually a result of: (AFMC 1996)
(a) Segregation (b) Hybridization
(c) Non-disjunction (d) Crossing over

232. The complete set of chromosomes, inherited as a single unit, from one parent, is known as: (AIIMS 1994)
(a) Linkage (b) Genotype
(c) Gene pool (d) Genome

233. Induction of mutation by X-rays was discovered by: (MPPMT 1996)
(a) Muller (b) Morgan
(c) Hugo de Vries (d) Luria

234. If a homozygous red-flowered plant is crossed with a homozygous white-flowered plant, the offspring will be: (MPPMT 1997)
(a) All red-flowered (b) All white-flowered
(c) Half red-flowered (d) Half white-flowered

235. What would be the colour of flowers in F_1 progeny as a result of a cross between homozygous red and homozygous white-flowered snapdragon? (MPPMT 1997)
(a) Red (b) White
(c) Red and white (d) Pink

236. Gynandromorph is a condition in which the body of an individual exhibits:
(a) Only female characters
(b) Only male characters
(c) Male and female characters both
(d) Either male or female characters

237. Phenocopies are the individuals of:
(a) Different genotype but same phenotype
(b) Same genotype and same phenotype

(c) Same genotype but different phenotype
(d) None of the above

*238. In sweet pea, genes C and P are necessary for colour in flowers. The flowers are white in the absence of either or both the genes. What will be the percentage of coloured flowers in the offspring of the cross Ccpp × ccPp? (AIIMS 1997)
(a) 100% (b) 75%
(c) 50% (d) 25%

239. Somatic mutations are also called:
(a) Bud sports
(b) Bud mutations or bud sports
(c) Bud mutations
(d) Spontaneous mutations

240. The process of removing stamens from a flower during hybridization is called:
(a) Emasculation (b) Selfing
(c) Penetrance (d) Crossing

241. The crosses between two unrelated pure breeding populations are called:
(a) Heterosis (b) Outbreeding
(c) Inbreeding (d) Hybrid vigour

242. Multiples alleles always influence:
(a) No character (b) Same character
(c) Different character (d) None of these

243. Mutations, when they are permanent heritable and occur within a gene or cistron of the DNA molecules, are called:
(a) Additional mutations (b) Point mutations
(c) Chromosomal mutations (d) Deletion mutations

244. Pleiotropic genes are those genes which have:
(a) Multiple effect (b) No effect
(c) Single effect (d) Double effect

245. Mutant genes that give slightly modified phenotypes are called:
(a) Heteroalleles (b) Recessive alleles
(c) Isoalleles (d) Dominant alleles

246. If a diploid species has two similar sets of chromosomes or genomes (AA), tetraploid of this species will have the following genetic constitution:
(a) AAAA (b) AAA
(c) AA (d) Tetraploid is not possible

247. Chromosome mutation involves:
(a) Change in no. of genes
(b) Change in no. of chromosomes
(c) Change in arrangement of genes
(d) All of the above

248. A single branch may bear leaves, flowers or fruits different from other parts of the plant. This type of mutation is called:
(a) Point mutation (b) Deletion mutation
(c) Somatic mutation (d) Gametic mutation

249. Mutation rate is affected by:
(a) Environmental control (b) Genetic control
(c) Viral control (d) All of these

250. Background mutations are also called:
(a) Gross mutations (b) Induced mutations
(c) Spontaneous mutations (d) Inversion

251. Law of independent assortment was proposed by: (EAMCET 1994)
(a) Carolus Linnaeus (b) Melvin Kelvin
(c) Robert Hooke (d) Gregor Johann Mendel

252. To determine heterozygosity or homozygosity a plant must be crossed with: (MPPMT 1991)
(a) Recessive (b) Dominant
(c) Homozygous dominant (d) Heterozygous dominant

253. When an individual is having both the alleles of contrasting characters, it is said to be:
(a) Homozygous (b) Heterozygous
(c) Dioecious (d) Monoecious

254. Mendelian recombinations are due to:
(a) Independent assortment of genes
(b) Linkage of genes
(c) Mutation
(d) Dominance

255. When a cross is made between offspring and its parents, it is known as: (MPPMT 1993)
(a) Monohybrid cross (b) Dihybrid cross
(c) Back cross (d) Reciprocal cross

256. Mendel was lucky in selecting pea plants for his experiment on heredity because: (CPMT 1992)
(a) Pea plants belong to family Leguminosae
(b) They show red coloured flowers
(c) They have round seeds full of protein
(d) The seven characters he selected were on seven different chromosomes

257. Which procedure of Mendel differed from those of his predecessors and contributed most to his success?
(a) He quantitatively analysed his data
(b) He kept breeding records
(c) He observed distinct inherited traits
(d) He observed many characteristics for each trait

258. Crossing over is advantageous because it brings about: (CPMT 1991)
(a) Variation (b) Linkage
(c) Inbreeding (d) Stability

259. Colour blindness is a:
(a) Sex-influenced character
(b) Sex-limited character
(c) Sex-linked character
(d) None of the above

260. Haemophilia in human beings is caused due to: (CPMT 1992)
(a) Chromosomal abberation
(b) Autosomal mutation
(c) Sex-linked mutation
(d) None of the above

261. Mutations in plants are induced by:
(a) Visible light (b) Infrared rays
(c) X-rays (d) Radio waves

262. When a diploid plant (female) is crossed with a tetraploid (male), the ploidy of the endosperm cells in the resulting seeds is:
(a) Diploid (b) Triploid
(c) Tetraploid (d) Pentaploid

263. Acridine dyes cause:
(a) Substitution mutations (b) Transitions
(c) Frameshift (d) Transversions

264. The plant of *Cynodon* (doob grass) is usually:
(a) Trisomic (b) Monoploid
(c) Monosomic (d) Triploid

265. The chemicals like 5-BU, 2-AP (*i.e.*, base analogue) induce:
(a) Frameshift (b) Transitions
(c) Transversions (d) None of these

266. In barley $2n = x = 7$, the plants are called:
(a) Autohaploids (b) Haploids
(c) Monohaploids (d) Monoploids

*267. A plant having chromosomal constitution as AABBBCCDD is a:
(a) Monosomic (b) Trisomic
(c) Amphidiploid (d) Nullisomic

268. Who were awarded Nobel Prize in 1958 for their work on bread mold (*Neurospora*)?
(a) Beadle and Watson (b) A.E. Garrod and P. Tatum
(c) Beadle and Tatum (d) Tatum and Garrod

269. Match the following:
I. Genetics II. Checker board
III. Haploid IV. Allele
A. Single set of chromosome
B. Heredity and variation
C. Punnett
D. Factors which control contrasting expression of a character:
(a) I-A, II-C, III-B, IV-D (b) I-B, II-C, III-A, IV-D
(c) I-C, II-B, III-A, IV-D (d) I-D, II-A, III-B, IV-C

270. Match the following:
I. Polysome II. Recon III. Synapsis IV. Tetraploid
A. Unit of DNA capable of undergoing recombination
B. Ribosome bound to mRNA during protein synthesis
C. $4n$
D. Pairing of homologous chromosomes:
(a) I-B, II-D, III-A, IV-C (b) I-A, II-B, III-C, IV-D
(c) I-B, II-A, III-D, IV-C (d) I-A, II-B, III-D, IV-C

271. Match the following:
I. Gamete II. Homozygous
III. Heterozygous IV. Albino
A. Colourless individual
B. Haploid cell
C. When both factors are identical
D. When both factors are different:
(a) I-B, II-C, III-D, IV-A (b) I-D, II-C, III-A, IV-B
(c) I-A, II-B, III-C, IV-D (d) I-D, II-B, III-C, IV-A

272. Law of dominance and recessiveness is the result of: (CPMT 1993)
(a) Back cross (b) Incomplete dominance
(c) Dihybrid cross (d) Monohybrid cross

273. Back cross is a cross between:
(a) $F_1 \times F_1$ (b) $F_1 \times$ recessive
(c) $F_1 \times$ Dominant (d) $F_1 \times$ any parent

274. In a cross between AABB × aabb, the ratio of genotype in F_2 generation between AABB, AaBB, Aabb, aabb, would be: (CBSE 1992)
(a) 9 : 3 : 3 : 1 (b) 1 : 2 : 2 : 1
(c) 7 : 5 : 3 : 1 (d) 2 : 1 : 1 : 2

275. Mendel was:
(a) A physiologist (b) A plant breeder
(c) A cytologist (d) A taxonomist

276. Some people experience PTC paper on tongue as bitter, others as tasteless. This character is hereditary in nature. Suppose T stands for dominant gene and t stands for recessive gene, the genetic make up of a person who cannot taste is?
(a) TT (b) Tt
(c) tt (d) None of these

277. Mendel's experiment of dihybrid was based on: (CPMT 1991)
(a) Green cotyledon, round seed × yellow cotyledon, wrinkled seed
(b) Tall plant, red flower × dwarf plant, white flower
(c) Yellow cotyledon, round seed × green cotyledon, wrinkled seed
(d) Tall plant, yellow flower × dwarf plant, pink flower

278. What phenotypic ratio would you expect when a capsulated pathogenic strain of *Pneumococcus* is allowed to meet a non-capsulated non-pathogenic strain?
(a) 3 : 1 (b) 1 : 2 : 1
(c) 9 : 3 : 3 : 1 (d) None of these

279. A tobacco plant heterozygous for albinism (a recessive character) is self-pollinated and 1200 seeds are subsequently germinated. How many seedlings would have the parental genotype?
(a) All (b) 600
(c) 300 (d) None of these

280. Mendelian inheritance is the inheritance of:
(a) Prokaryotes (b) Protists
(c) Haploid individuals (d) Diploid individuals

281. The expression of character of a distant ancestor (not present in parents) in an individual is called:
(a) Reversion (b) Atavism
(c) Both (a) and (b) (d) Neither (a) nor (b)

282. Why were pea plants more suitable than dogs for Mendel's experiment?
(a) There were no pedigree records of dogs
(b) Pea plants can be self-fertilised
(c) All pea plants have $2n$ number of chromosomes
(d) Dogs have many genetic traits
(e) Dogs have different colours

283. Gene for red colour is completely dominant. If a plant with genotype Rr is selfed, then the genotypes of offsprings would be in the ratio:
(a) 1 : 2 : 1 (b) 3 : 1
(c) 9 : 3 : 3 : 1 (d) None of these

284. Dominant gene for tallness is T and for yellow colour is Y. A plant heterozygous for both the traits is selfed, then the ratio of pure homozygous dwarf and green offspring would be:
(a) 1/4 (b) 4/6
(c) 3/16 (d) 1/16

285. Hybridisation means:
(a) Removal of stamens
(b) Mixing parental characters
(c) Production of large-sized grains
(d) Study of pollination habit

286. Mendel performed his researches on pea plants in the:
(a) University of Vienna
(b) University of Austria
(c) Monastery of Brunn
(d) Preparatory school of Brunn

287. Independent assortment refers to:
(a) Separation of characters of one parent
(b) Non-separation of characters of one parent
(c) Combination of parental characters
(d) Separation of parental characters

288. Mendel formulated the law of purity of gametes on the basis of: **(Raj. PMT 1990)**
(a) Dihybrid cross (b) Monohybrid cross
(c) Back cross (d) Test cross

289. The first geneticist was:
(a) Engler (b) Mendel
(c) Schwann (d) Miller

290. In order to determine whether variations of a character in population were genetically controlled, the most appropriate procedure would be to:
(a) Measure the variations and see if they are continuous or discontinuous
(b) Cross individuals of both extremes and see if the offsprings and the parents show the same range of variations
(c) Count the chromosomes and find out the variations in the number in their population
(d) Examine the DNA and see if the population shows any variation

291. Knowing that albinism is determined by a recessive gene in man, the presence of albinism in the children born to a couple proves that: **(AIIMS 1990)**
(a) Both the father and mother are heterozygous for albinism
(b) The father is homozygous normal but the mother is heterozygous or *vice-versa*
(c) The father is homozygous for albinism but the mother is heterozygous or *vice-versa*
(d) Both (a) and (b) are correct
(e) Both (a) and (c) are correct

292. Which of Mendel's procedures differed from those of his predecessors and contributed most to his success?
(a) He kept his breeding records
(b) He observed many characteristics for each trait
(c) He observed distinct inherited traits
(d) He quantitatively analysed his data

293. Independent assortment of Mendel was proved by: **(CPMT 1993)**
(a) Monohybrid cross (b) Dihybrid cross
(c) Back cross (d) Incomplete dominance

294. Which of the following is a test cross? **(AIIMS 1999)**
(a) Tt × Tt (b) Tt × tt
(c) Tt × TT (d) TT × tt

295. In a monohybrid cross, pure homozygous plant will be: **(EAMCET 1991)**
(a) 9 (b) 2
(c) 1 (d) 4

296. The appearance of a hidden character in some progeny of F_2 proclaims the: **(CPMT 1990)**
(a) Law of purity of gametes
(b) Law of dominance
(c) Law of independent assortment
(d) Law of segregation

297. The year 1900 AD is highly significant for the geneticists due to:
(a) Discovery of genes
(b) Principles of linkage
(c) Chromosome theory of heredity
(d) Rediscovery of mendelism

298. Test cross is defined as:
(a) Cross between parents to find out the genotype of the parents
(b) Cross between the hybrid and the dominant parent
(c) Cross between the hybrid and the recessive parent
(d) All of the above

299. The Punnett square shown below represents the pattern of inheritance in dihybrid cross when yellow (Y) is dominant over white (y) and round (R) is dominant over wrinkled (r) seeds:

	YR	Yr	yR	yr
YR	F	J	N	R
Yr	G	K	O	S
yR	H	L	P	T
yr	I	M	Q	U

A plant of type 'H' will produce seeds with the genotype identical to seeds produced by the plants of:
(a) Type M (b) Type J
(c) Type P (d) Type N

300. If haploid number of chromosomes is 10, what would be the number in monosomic and tetrasomic?
(a) 10 and 40 (b) 19 and 22
(c) 9 and 22 (d) 19 and 40

301. If haploid number of chromosomes is 10, what is the tetrasomic number?
(a) 10 (b) 20
(c) 22 (d) 40

302. An organism or cell having a chromosome number which is higher than the exact multiple of the basic number is known as?
(a) Hypoploid (b) Allopolyploid
(c) Hyperploid (d) Autopolyploid

303. If the haploid number of chromosomes is 12, what shall be the number of chromosomes in monosomic:
(a) 22 (b) 23
(c) 25 (d) 26

304. For a plant or animal to be fit for genetic studies, it should have:
(a) Distinct differentiating characters
(b) Large number of progeny

(c) Short life cycle
(d) All of the above

305. Inversions and deletions are examples of:
(a) Gene mutations (b) Cell mutations
(c) Chromosomal mutations (d) None of these

306. The carriers of colour blindness and haemophilia are:
(a) Females (b) Males
(c) Both (a) and (b) (d) None of these

307. Concept of quantitative inheritance was first given by:
(a) Mendel (b) Nilsson-Ehle
(c) Hugo de Vries (d) Darwin

308. Universal law of Mendel is:
(a) Law of segregation (b) Law of purity of gametes
(c) Law of dominance (d) Both (a) and (b)

309. Gene position on chromosomes represents the term:
(a) Locus (b) Allelomorph
(c) Gene point (d) None of these

310. Which of the following terms is involved in crossing over?
(a) Chiasmata (b) Recombination
(c) Terminalization (d) All of these

311. Example of polygenic inheritance is:
(a) Cob length in corn (b) Kernel colour in wheat
(c) Skin colour in man (d) All of these

312. Tendency of genes to be inherited together is known as:
(a) Dominance (b) Linkage
(c) Crossing over (d) Translocation

313. Pleiotropic genes have: (AMU 1991)
(a) Multiple genotype (b) Single genotype
(c) Single phenotype (d) Multiple phenotype

314. Dominant lethal gene is responsible for:
(a) Allowing the organism to survive but not to reproduce
(b) Allowing the organism to survive and reproduce
(c) Killing the organism
(d) Determining sex of organism

315. F_2 ratio in chicken comes out to be 9 rose black comb, 1 single white comb, 3 rose comb white and 3 single comb black. Which are the recessive? (APMEE 1996)
(a) Single comb, white plumage
(b) Rose comb, white plumage
(c) Single comb, black plumage
(d) Rose comb, white plumage

316. Red seed colour shown in F_2 ratio of 1 : 4 : 6 : 4 : 1. It is due to: (DPMT 1996)
(a) Two polygenes
(b) Different number of dominant genes
(c) Different number of recessive genes
(d) Supplementary genes

317. Multiple alleles control inheritance of: (CBSE 1991; MPPMT 2002)
(a) Phenylketonuria (b) Colour blindness
(c) Sickle cell anaemia (d) Blood group

318. A polygenic inheritance in human being is: (CBSE 1993)
(a) Skin colour (b) Phenylketonuria
(c) Colour blindness (d) Sickle cell anaemia

319. The phenomenon of exchange of segments between paternal and maternal chromosomes is called: (CBSE 1996)
(a) Linkage (b) Recombination
(c) Crossing over (d) Segregation

320. The homozygous and heterozygous individual for a quantitative trait would have: (CBSE 1996)
(a) Different phenotype (b) The same phenotype
(c) Supplementary gene (d) Epistatic gene

321. Gene A and B are necessary for normal hearing. What is the possible genotype of a normal child of deaf mother/father? (Raj. PMT 1992)
(a) aabb (b) aaBB (c) AaBb (d) Aabb

322. In a dihybrid cross, two recessive genes show 10% recombinants. The distance between two genes is:
(a) 10 map unit (b) 20 map unit
(c) 30 map unit (d) 40 map unit

323. Which of the following is suitable for experiment on linkage? (CBSE 1993)
(a) aaBB × aaBB (b) AABB × aabb
(c) AaBb × AaBb (d) AAbb × AaBB

324. Linked genes separate due to: (CPMT 1994, 97)
(a) Recombination (b) Mutation
(c) Crossing over (d) None of these

325. An example of disease of molecular mutations is: (MPPMT 1994)
(a) Sickle cell anaemia (b) Erythroblastosis foetalis
(c) Haemophilia (d) Anaemia

326. In human, height shows a lot of variation. It is an example of: (DPMT 1996)
(a) Multiple alleles (b) Pleiotropic inheritance
(c) Polygenic inheritance (d) Pseudoalleles

327. Linkage was discovered in animals by: (MDAT Bihar 1996)
(a) Punnett (b) Mendel
(c) Muller (d) Morgan

328. Two genes situated very close on the chromosome show: (AFMC 1994)
(a) High crossing over
(b) Hardly any crossing over is detected
(c) No crossing over
(d) Only double cross over can occur

329. Mendel found that some traits do not assort independently. Later workers found it due to: (MPPMT 1995)
(a) Linkage
(b) Crossing over
(c) Amitosis
(d) Dominance of one trait over another

330. Crossing over occurs between:
(a) Two non-sister chromatids of a homologous pair of chromosomes
(b) Two chromatids of any chromosome
(c) Two chromatids of same chromosome
(d) All the foregoing

331. Major source of variations is: (CPMT 1991)
(a) Polyploidy (b) Mutations
(c) Chromosome aberration (d) Segregation

332. Mutation is a change that is: (BHU 1991)
(a) Never inherited
(b) Inherited only in F_2 generation
(c) Inherited
(d) Responsible for plant growth

333. Which crop variety is not due to induced mutation? (CBSE 1993)
(a) Reimei of rice
(b) Prabhat of arhar
(c) Sharbati Sonora of wheat
(d) Aruna of castor

334. Out of 8 ascospores formed in *Neurospora*, the arrangement is 2a : 4a : 2a showing: (CBSE 1994)
(a) No crossing over
(b) Some meiosis
(c) Second generation division
(d) First generation division

335. A strong mutagen is: (JKMCEE 1994)
(a) Cold (b) Heat
(c) Water (d) X-ray

336. Man made cereal is: (BHU 1995)
(a) *Triticum* (b) *Hordeum*
(c) *Triticale* (d) *Eleusine*

337. Recessive mutations are expressed in: (MPPMT 1991)
(a) Homozygous condition (b) Heterozygous condition
(c) Next generation (d) Same generation

338. Number of linkage in a polynucleotide would be: (DPMT 1996)
(a) Same as number of nucleotides
(b) Twice the number of nucleotides
(c) One less than the number of nucleotides
(d) One

339. Which is not a mutagen? (MPPMT 1995)
(a) Acetic acid (b) Gamma ray
(c) Nitrous acid (d) Hydroxyl amine

340. Rate of mutation is affected by: (MPPMT 1997)
(a) Temperature (b) X-ray
(c) Gamma and beta ray (d) All of these

341. Which genotype will indicate colour blindness in male? (MDAT Bihar 1996)
(a) X^cY (b) X^cY^c
(c) X^cX^c (d) A^cA^c

342. Foetal sex can be determined by examining cell from amniotic fluid looking for: (CBSE 1991)
(a) Barr body (b) Chromosomes
(c) Chiasmata (d) Kinetochores

343. Transition in gene mutation occurs when? (MPPMT 1997)
(a) GC is substituted by TA (b) CG is substituted by GC
(c) AT is substituted by CG (d) AT is substituted by GC

344. Albinism is a congenital disorder resulting from the lack of enzyme: (CBSE 1994)
(a) Tyrosinase (b) Fructokinase
(c) Catalase (d) Xanthine oxidase

345. Number of chromosomes can increase or decrease due to: (AFMC 1996)
(a) Mutation (b) Genetic repetition
(c) Nondisjunction (d) All of these

346. Low temperature is mutagenic in: (BHU 1994)
(a) Wheat (b) Maize
(c) Rice (d) Mustard

347. Gynandromorph is: (CPMT 1996)
(a) Male with female trait
(b) Female with male trait
(c) Half male and half female
(d) None of the above

348. Complete haploid set of chromosomes of a species is: (Manipal 1995)
(a) Genome (b) Plasmon
(c) Genotype (d) Genotroph

349. XXY chromosome complement is found in: (CPMT 1994)
(a) Down's syndrome (b) Turner's syndrome
(c) Klinefelter's syndrome (d) Super female

350. A mutagenic/alkylating agent which is commonly used is: (AIIMS 1994)
(a) Ethyl dibromide (b) Endrin
(c) Griseofulvin (d) All of these

351. Inheritance of total colour blindness is: (CBSE 1992)
(a) Y-linked (b) XY-linked
(c) X-linked (d) XX linked

352. One barr body is found in man of genotype:
(a) XY (b) XXXY
(c) XXY (d) XX

353. Which chromosome set is found in male grasshopper? (MDAT Bihar 1995)
(a) XY (b) X
(c) YY (d) XX

354. For evolutionary success a mutation must occur in: (MPPMT 1996)
(a) Germplasm DNA (b) Somatic RNA
(c) Germplasm RNA (d) Somatic DNA

355. Number of genes on a chromosome is: (CPMT 1996)
(a) One (b) Ten
(c) Thirty five (d) Infinite

356. Genetic drift: (AFMC 1995)
(a) Is the random change in gene frequencies
(b) Has nothing in common with inbreeding
(c) Is an orderly change in gene frequencies
(d) Produces greatest fluctuations in large populations

357. Different types of chromosomes can be recognised by the position of: (AIIMS 1996)
(a) Gene (b) Chromosome
(c) Centromere (d) Spindle

358. A child gets sex-linked trait from: (MDAT Bihar 1994)
(a) Father (b) Mother
(c) Both (a) and (b) (d) None of these

359. XY sex chromosomes were discovered by: (BHU 1994)
(a) G.J. Mendel (b) M.J.D. White
(c) Nettil Stevans (d) R. Brown

360. Mutation rates are affected by: (MPPMT 1997)
(a) Temperature
(b) X-rays
(c) Gamma and beta radiations
(d) All of the above

361. The basis for DNA fingerprinting is: (CBSE 1996)
(a) Occurrence of restriction fragment length polymorphism
(b) Phenotypic differences between individuals
(c) Availability of cloned DNA
(d) Knowledge of human karyotype

362. Genic balance theory of sex determination was proposed by: (MPPMT 1997)
(a) Morgan (b) Bridges
(c) Boveri (d) Wilkins

363. Gynandromorph develops in *Drosophila* when the two cells in the two-celled proembryo will have one of the following chromosomal sets: (MPPMT 1997)
(a) 2A + XX in one cell and 2A + X in the other
(b) 2A + X in both the cells
(c) 2A + XXX in both the cells
(d) All of the above

364. Amniocentesis is a technique: (CBSE 1997)
(a) By which the essential amino acids in the body can be estimated
(b) By which any chromosomal anomalies in the foetus can be detected
(c) In which the sex of the foetus can be reversed
(d) That can be used for correcting genetic disorders of the foetus

365. If a haemophilic man marries a normal lady, the offspring will be: (MPPMT 1997)
(a) All haemophilic (b) All normal
(c) Haemophilic daughters (d) Haemophilic sons

366. A normal woman whose father was colourblind marries a normal man. What kind of children would be expected and in what proportion? (MPPMT 1997)
(a) Daughters normal 50% of sons, colourblind
(b) Daughters normal, all sons colourblind
(c) 50% of daughters colourblind, all sons normal
(d) All daughters colourblind, sons normal

367. If haploid chromosome number in a cell is 12, then the monosomic number will be: (MPPMT 1994)
(a) 25 (b) 22
(c) 26 (d) 23

368. Law of independent assortment can be proved by:
(a) Test cross (b) Back cross
(c) Monohybrid cross (d) Dihybrid cross

*369. If a character is always transmitted directly from a father to all his sons and from their sons to all their sons, then which chromosome carries the gene for the character? (MPPMT 1997)
(a) Autosome (b) X-Chromosome
(c) Y-Chromosome (d) None of these

370. Which are X-linked recessive traits in human male? (CPMT 1997)
(a) Leisman's syndrome (b) Sickle cell anaemia
(c) Hunter's syndrome (d) Colour blindness

371. A human with chromosome number 44 + XXY is male, such a person suffers from: (MPPMT 1997)
(a) Turner's syndrome (b) Klinefelter's syndrome
(c) Down's syndrome (d) Paton syndrome

372. A mutation at one base of the first codon of a gene produces a non-functional protein. Such a mutation is called: (CBSE 1997)
(a) Non-sense mutation (b) Mis-sense mutation
(c) Frameshift mutation (d) Reverse mutation

373. When a hybrid pea plant for yellow round seeds (YyRr) is self-pollinated, the phenotypic ratio in the next generation would be? (CET Karnataka 1997)
(a) 12 : 3
(b) 9 : 3 : 3 : 1
(c) 9 : 7
(d) 1 : 2 : 2 : 1 : 4 : 1 : 2 : 2 : 1

374. Different mutations referable to the same locus of chromosome give rise to a: (CBSE 1997)
(a) Multiple alleles (b) Pseudoalleles
(c) Polygenes (d) Oncogenes

375. Sickle cell anaemia is caused due to: (AFMC 1997)
(a) Change in α-chain
(b) Change in glutamic acid from valine in β-chain
(c) Change in valine from glutamic acid in α-chain
(d) Change in valine from glutamic acid in β-chain

376. Genetic identity of a human male is determined by: (CBSE 1997)
(a) Autosome (b) Nucleolus
(c) Sex chromosomes (d) Cell organelles

377. How many gametes will be formed from AaBbCc? (Pb. PMT 1997)
(a) 8 (b) 16
(c) 4 (d) 20

378. What will be the genotype of F_1 upon crossing AaBb aabb? (Pb. PMT 1997)
(a) AaBb (b) AaBb, Aabb, aaBb, aabb
(c) AaBb (d) AaBb and aabb

379. A fruitfly is heterozygous for sex-linked genes. When mated with a normal female fruitfly, the male specific chromosome will enter egg cells in the proportion of: (CBSE 1997)
(a) 1 : 1 (b) 1 : 2 (c) 3 : 1 (d) 7 : 1

380. In *Drosophila* white eye colour is due to recessive genes and is sex-linked. If white eyed female is crossed with red eyed male, the % of female having red coloured eye is: (CPMT 1997)
(a) 0% (b) 50%
(c) 25% (d) 100%

381. The plants having same genotype are called: (CPMT 1998)
(a) Population (b) Community
(c) Clone (d) Group

382. The chromosome aberration means: (CPMT 1998)
(a) Euploidy
(b) Aneuploidy
(c) Change in chromosome part
(d) All of the above

383. Cytoplasmic inheritance is also called: (CPMT 1998)
(a) Parental inheritance (b) Maternal inheritance
(c) Paternal inheritance (d) Genetic inheritance

384. Linkage prevents: (CPMT 1998)
(a) Homozygous condition (b) Heterozygous condition
(c) Hybrid formation (d) Segregation of alleles

385. When two alleles of a gene are present and both dominant, the situation is called: (CPMT 1998)
(a) Incomplete dominance (b) Co-dominance
(c) Inhibition (d) Epistasis

386. In dihybrid test cross, we get ratio: (CPMT 1998)
(a) 1 : 1 : 1 : 1 (b) 1 : 2 : 1
(c) 1 : 4 : 4 : 1 (d) 3 : 5 : 5 : 3

387. When heterozygous is crossed with homozygous recessive, the cross is called: (CPMT 1998)
(a) Back cross (b) Test cross
(c) Lethal cross (d) Parental cross

388. What base is responsible for hot spots for spontaneous point mutations? (CBSE 1998)
(a) Adenine (b) Guanine
(c) 5-bromouracil (d) 5-methyl cytosine

389. If Mendel had studied the 7 traits using a plant with 12 chromosomes instead of 14, in what way would his interpretation have been different? (CBSE 1998)
(a) He would have discovered blending or incomplete dominance
(b) He would have mapped the chromosome
(c) He would not have discovered the law of independent assortment
(d) He would have discovered linkage

390. The formation of multivalents at meiosis in a diploid organism is due to: (CBSE 1998)
(a) Reciprocal translocation (b) Deletion
(c) Monosomy (d) Inversion

391. A woman with two genes for haemophilia and a gene for colour blindness on one of the 'X' chromosomes marries a normal man. How will the progeny be? (CBSE 1998)
(a) Haemophilic and colourblind daughters
(b) All sons and daughters haemophilic and colourblind
(c) 50% haemophilic colourblind sons and 50% normal sons
(d) 50% haemophilic daughters and 50% colourblind daughters

392. How many different types of genetically different gametes will be produced by a heterozygous plant having the genotype AABbCc? (CBSE 1998)
(a) Nine (b) Two (c) Four (d) Six

393. Crossing over in diploid organism is responsible for: (CBSE 1998)
(a) Recombination of linked alleles
(b) Segregation of alleles
(c) Dominance of genes
(d) Linkage between genes

*394. How many genome types are present in a typical green plant cell? (CBSE 1998)
(a) More than ten (b) Two
(c) Three (d) More than five

395. In Down's syndrome, karyotyping has shown that the disorder is associated with trisomy of chromosome number-21 usually due to: (CBSE 1998)
(a) Addition of extra chromosome during mitosis of the zygote
(b) Non-disjunction during egg-cell formation
(c) Non-disjunction during sperm-cell formation
(d) Non-disjunction during formation of egg-cells and sperm-cells

396. In human beings, multiple genes are involved in the inheritance of: (AFMC 1998)
(a) Colour blindness (b) Phenylketonuria
(c) Sickle cell anaemia (d) Skin colour

*397. Haemophilia is a genetic disorder, in which: (AFMC 1998)
(a) Blood fails to coagulate after an injury
(b) There is delayed coagulation of blood
(c) Blood clots in blood vessels
(d) Blood cell count falls

398. In maize, coloured endosperm (C) is dominant over colourless (c) and full endosperm (R) is dominant over shrunken (r). When a dihybrid of F_1 gen. was test crossed, it produced four phenotypes in the following percentage:

Coloured full	48%
Coloured shrunken	5%
Colourless shrunken	7%
Colourless shrunken	48%

From this data, what will be the distance between two non-allelic genes:
(a) 48 units (b) 5 units
(c) 7 units (d) 12 units

399. Based on relative proportion of parental and recombinant phenotypes in the test cross progeny involving two recessive genes r (round) and y (yellow) controlling the seed shape and seed colour respectively, the observed per cent recombination is 10. The distance between r and y is:
(a) 10 m.u. (b) 20 m.u.
(c) 30 m.u. (d) 40 m.u.

400. If two genes a and b are linked and show 20% recombination, the proportion of gametes produced in F_1 by a dihybrid ++/ab derived from a cross between ++/++ and ab/ab would be:
(a) ++80 : ab20
(b) ++50 : ab50
(c) ++40 : ab40 : +a10 : +b10
(d) ++20 : ab20 : +a20 : +b20

401. Unit used for expressing the distance between two genes on chromosome is:
(a) Centimeters (b) CentiMorgans
(c) Angstrom- (d) Microns

402. For preparation of genetic maps, the recombination frequencies between genes are additive over short distances, but not over long distances, due to: (BHU 1994)
(a) Multiple cross overs (b) Epistasis
(c) Lethal mutations (d) Synaptonemal complex

403. If two alleles come together, only one is able to express itself, it is known as: (CBSE 1999)
(a) Law of dominance
(b) Law of segregation
(c) Law of incomplete dominance
(d) Law of independent assortment

*404. Red-green colour blindness in human beings is governed by a sex-linked recessive gene. A normal woman whose father was colourblind marries a colourblind man. What proportion of their daughters is expected to be colourblind? (CBSE 1999)
(a) 0/1 (b) 1/2
(c) 1/4 (d) All

*405. What proportion of the offsprings of the cross AABBCC × AaBbCc will be completely heterozygous for all the genes segregated independently? (CBSE 1999)
(a) 1/8 (b) 1/4
(c) 1/2 (d) 1/16

406. Minor changes at gene level are called: (CBSE 1999)
(a) Point mutations (b) Chromosomal mutations
(c) Reverse mutations (d) Forward mutations

*407. A haemophilic man marries a normal homozygous woman. What is the probability that their son will be haemophilic? (CPMT 1999; CET Karnataka 2002)
(a) 1/2 (b) 1/4
(c) 1/6 (d) 0

408. When we cross red flowered variety of *Mirabilis jalapa* with white flowered variety, we get pink flowers. This is called: (CPMT 1999; AIIMS 2001)
(a) Complete dominance (b) Incomplete dominance
(c) Co-dominance (d) Epistasis

409. Cause of appearance of parental characters in Mendel's F_2 generation is explained by: (CPMT 1999)
(a) Linkage (b) Crossing over
(c) Dominance (d) None of these

410. Maternal inheritance is due to: (CPMT 1999)
(a) Nuclear genes (b) Cytoplasmic genes
(c) Split genes (d) Pseudogenes

411. Cuenot, a French geneticist, performed experiments on: (BHU 1999)
(a) *Oenothera* (b) Mice
(c) *Antirrhinum* (d) None of these

412. For a particular character, when two genes are required, these are called: (BHU 1999)
(a) Complementary genes (b) Epistatic genes
(c) Supplementary genes (d) None of these

413. 25 : 46 : 26 ratio is expected from which cross? (AIIMS 1999)
(a) AA × aa (b) Aa × Aa
(c) AA × AA (d) aa × aa

*414. How many types of gametes are produced by AaBbCcDd? (AIIMS 1999)
(a) 2 (b) 8
(c) 16 (d) 24

415. Which is the dominant character in Mendelian experiments? (AIIMS 1999)
(a) Yellow pod colour
(b) Yellow colour of cotyledons
(c) White seed coat
(d) Wrinkled seed form

416. Trisomy of 21st chromosome is found in: (CBSE 2000, 2002)
(a) Turner's syndrome (b) Down's syndrome
(c) Klinefelter's syndrome (d) All of these

417. Mutation is generally due to: (CBSE 2000)
(a) Lethal gene (b) Recessive gene
(c) Dominant gene (d) Complementary gene

418. Which is correct about Mendelian characters? (CBSE 2000)
(a) Tall plants are dominant over dwarf
(b) Green pods are recessive over yellow pods
(c) Constricted pods are dominant over inflated pods
(d) All of these

419. Red flowers (RR) are dominant over white flowers (rr) Tall plants (TT) are dominant over dwarf plants (tt). If plant with genotype TTRr is crossed with ttrr plant, ther what percentage will have red flowers on tall plants? (CBSE 2000
(a) 20% (b) 25%
(c) 50% (d) 100%

*420. A cross is made between pure tall and yellow pod plan and pure dwarf and green pod plant. Calculate the numbe of dwarfs in F_2 generation: (CPMT 2000
(a) 3 (b) 1
(c) 9 (d) 4

421. Crossing over occurs in: (CPMT 2000
(a) Mitosis (b) Meiosis
(c) Only somatic cells (d) All of these

*422. A couple has six daughters. What is the possibility of thei having a girl next time? (AFMC 2000)
(a) 10% (b) 50%
(c) 90% (d) 100%

423. Laws of inheritance were proposed by: (AFMC 2000)
(a) Mendel (b) Darwin
(c) Morgan (d) Bateson

424. The ratio of F_2 generation of dihybrid cross is: (AFMC 2000)
(a) 1 : 1 : 1 : 1 (b) 9 : 3 : 3 : 1
(c) 3 : 1 (d) 1 : 2 : 1

425. Mendel is called the father of: (MPPMT 2000)
(a) Palaeobotany (b) Genetics
(c) Taxonomy (d) None of these

426. A cross between two pairs of alleles is called: (MPPMT 2000)
(a) Crossing over (b) Linkage
(c) Monohybrid cross (d) Dihybrid cross

427. Queen Victoria of England was: (CET Karnataka 2000)
(a) Haemophilic (b) Colourblind
(c) AIDS patient (d) Deaf

428. Persons who are colourblind cannot distinguish: (CET Karnataka 2000)
(a) Yellow and white (b) Green and blue
(c) Black and yellow (d) Red and green

429. A micromutation is: (BHU 2000)
(a) Polyploidy (b) Addition of chromosome
(c) Change in gene (d) Deletion of chromosome

430. First man-made cereal is: (BHU 2000)
(a) *Triticum* (b) ***Hordeum***
(c) *Triticale* (d) ***Eleusine***

431. Haemophilia is due to mutation in: (CPMT 2001)
(a) X-chromosome
(b) Y-chromosome
(c) Both X- and Y-chromosomes
(d) None of the above

432. Which of the following characters was not chosen by Mendel? (Uttaranchal PMT 2001)
(a) Pod shape (b) Pod colour
(c) Location of flower (d) Location of pod

433. Which of the following cross is used to determine heterozygosity or homozygosity of parents? (Uttaranchal PMT 2001)
(a) Test cross (b) Back cross
(c) Monohybrid cross (d) Dihybrid cross

434. A boy has a normal brother and a colourblind sister. What is true about his parents? (Uttaranchal PMT 2001)
(a) His father was normal but mother was colourblind
(b) His father was colourblind but mother was normal
(c) Both father and mother were colourblind
(d) Both father and mother were normal

435. Mendel chose 7 characters. Which of the following is dominant amongst them? (Manipal 2001)
(a) Constricted pod (b) Terminal flower
(c) Green pods (d) Green seeds

436. Balance theory of sex determination holds good for: (CET Karnataka 2001)
(a) *Drosophila* (b) *Allium cepa*
(c) Grasshoppers (d) Humans

437. Independent assortment of genes does not take place when: (CBSE 2001)
(a) Genes are located on homologous chromosomes
(b) Genes are linked and located on same chromosome
(c) Genes are located on non-homologous chromosome
(d) All of the above

438. Mendel obtained wrinkled seeds in pea due to deposition of sugars instead of starch. It was due to which enzyme? (CBSE 2001)
(a) Amylase
(b) Invertase
(c) Diastase
(d) Absence of starch branching enzyme

439. When dominant and recessive alleles express themselves together, it is called: (CBSE 2001)
(a) Co-dominance (b) Dominance
(c) Amphidominance (d) Pseudodominance

440. A and B genes are linked. What shall be genotype of progeny in a cross between AB/ab and ab/ab? (CBSE 2001)
(a) AAbb and aabb (b) AaBb and aabb
(c) AABB and aabb (d) None of these

441. Two non-allelic genes produce the new phenotype when present together but fail to do so independently, then it is called: (CBSE 2001)
(a) Epistasis
(b) Polygene
(c) Non-complementary gene
(d) Complementary gene

442. Extranuclear inheritance occurs in: (CBSE 2001)
(a) Killer *paramoecium* (b) Killer *amoeba*
(c) *Euglena* (d) *Hydra*

443. The polygenic genes show: (AIIMS 2000)
(a) Similar genotype (b) Different phenotype
(c) Different karyotype (d) Different genotype

444. During which disorder the blood clotting is delayed? (AIIMS 2000)
(a) AIDS (b) Cancer
(c) Haemophilia (d) Night blindness

445. Which disease has XXY chromosomal constitution? (AIIMS 2001; AFMC 2002)
(a) Down's syndrome (b) Turner's syndrome
(c) Klinefelter's syndrome (d) Okazaki syndrome

446. Extranuclear genes occur in: (AIIMS 2001)
(a) Plastids and inherited
(b) Plasmids and not inherited
(c) Mitochondria and inherited by male
(d) Mitochondria and inherited by female

*447. Discontinuous variations are: (AIIMS 2001)
(a) Mutations (b) Acquired characters
(c) Essential features (d) Non-essential features

448. Who is called 'Father of *Neurospora* genetics'?
(a) Lindegren (b) Beadle and Tatum
(c) Shear and Dodge (d) Bridges

449. *Neurospora* (red mould), an important experimental material in genetics, belongs to:
(a) Chlorophyceae class of algae
(b) Red algae
(c) Sac-fungi
(d) Club-fungi

450. Tetrad analysis in *Neurospora* confirms that crossing over occurs at:
(a) Single-stranded stage (b) 2-stranded stage
(c) 3-stranded stage (d) 4-stranded stage

451. Linkage was first studied by: (MPPMT 2001)
(a) Darwin (b) Morgan
(c) Bateson and Punnett (d) Mendel

452. How many types of genotypes are formed in F_2 progeny obtained from self-pollination of a dihybrid F_1? (MPPMT 2001)
(a) 9 (b) 3
(c) 6 (d) 1

453. If diploid number of chromosomes in a plant is 40, then the number of chromosomes in a gamete will be: (BHU 2001)
(a) 40 (b) 30
(c) 20 (d) 10

454. Haemophilia is a: [BCECE (P.T. Exam.) 2001]
(a) Deficiency disorder (b) Male sex disorder
(c) Female sex disorder (d) Autosomal sex disorder

455. Sex determination ratio in an organism is given by $\frac{X}{A} = 1.5$; then the organism will be: [BCECE (P.T. Exam.) 2001]
(a) Male (b) Female
(c) Super female (d) Intersex

456. Epistasis implies: [BCECE (P.T. Exam.) 2001]
(a) One pair of genes can completely mask the expression of another pair of genes
(b) One pair of genes independently controls a particular phenotype
(c) One pair of genes enhances the phenotype expression of another pair of genes
(d) Many genes collectively control a particular phenotype

457. A gamete normally contains: (CET Karnataka 2002)
(a) All alleles of a gene
(b) Many alleles of a gene

(c) One allele of a gene
(d) Two alleles of a gene

*458. A monohybrid cross between two plants, one having 24 cm long internodes and the other having 12 cm long internodes, produced F_1 hybrids all having 18 cm long internodes. This is a case of: (CET Karnataka 2002)
(a) Multiple allelism (b) Recessive dominance
(c) Incomplete dominance (d) Complete dominance

459. If a diploid (2*n*) plant is treated with colchicine, it will result in: (CBSE 2002)
(a) 2*n* (b) 4*n*
(c) 3*n* (d) 6*n*

460. Dominant allele is one, which can represent in: (CBSE 2002)
(a) Homozygous condition
(b) Heterozygous condition
(c) Both homozygous and heterozygous conditions
(d) None of the above

*461. The phenotypic ratio in F_2 generation, after selfing AABbCC of F_1, will be: (CBSE 2002)
(a) 1 : 1 (b) 9 : 3 : 3 : 1
(c) 3 : 1 (d) 27 : 9 : 9 : 9 : 3 : 3 : 3 : 1

*462. Which of the following diseases is governed by pleiotropic genes? (CBSE 2002)
(a) Sickle-cell anaemia (b) Haemophilia
(c) Colourblindness (d) None of these

463. Sex-linked disease is: (CBSE 2002)
(a) AIDS (b) Gonorrhoea
(c) Blindness (d) Haemophilia

464. In a family, father is having a disease and mother is normal. The disease is inherited to only daughters and not to the sons.-What type of disease is this? (CBSE 2002)
(a) Sex-linked recessive
(b) Sex-linked dominant
(c) Incompletely dominant
(d) Autosomal dominant

465. The alleles are: (CPMT 2002)
(a) Genes present in allosomes
(b) Genes governing eye characters
(c) Genes not taking part in reproduction process
(d) A pair of genes governing a specific character such as tallness or dwarfness

466. Lethal genes are those which cause death of the: (CPMT 2002)
(a) Homozygous infant being formed
(b) Individual in which they are present
(c) Heterozygous infant being formed
(d) All of the above

467. Hybrid vigour is induced by: (CPMT 2002)
(a) Crossing two plants
(b) Selection of plant
(c) Clonal selection of clones
(d) Species differentiation

468. Variations in characters are brought about by: (CET J & K 2002)
(a) Duplication of chromosomes during mitosis
(b) Mutations
(c) Crossing over during meiosis
(d) Both (b) and (c)

*469. A sex-linked recessive gene C produces red green colourblindness in humans. A normal woman whose father was colourblind marries a colourblind man. Of all the girls born to these parents, what percentage is expected to be colourblind? (JIPMER 2002)
(a) 25 per cent (b) 50 per cent
(c) 75 per cent (d) 100 per cent

470. Human syndromes arise due to chromosomal abnormalities. Which one of the following is resultant of monosomic condition? (JIPMER 2002)
(a) Klinefelter's syndrome (b) Turner's syndrome
(c) Down's syndrome (d) Edward's syndrome

471. Mendelian recombinations are due to: (DPMT 2001)
(a) Linkage
(b) Independent assortment of genes
(c) Mutations
(d) Dominant characters

472. How many types of gametes will be formed by the genotype DdEeFf? (Raj. PMT 2001)
(a) 3 (b) 8
(c) 27 (d) 6

473. In Snapdragon, when a red flowered plant is crossed with a white flowered one, the resultant hybrid plants have pink coloured flower. If plant of F_1 generation is crossed with a white flowered plant, the progeny will be: (Raj. PMT 2002)
(a) 10% red
(b) The red flower and white flower ratio is 3 : 1
(c) The pink flower and white flower ratio is 1 : 1
(d) The pink, red and white flower ratio is 1 : 2 : 1

474. When a monohybrid is crossed with a recessive parent, the cross is described as: (BHU 2002; MPPMT 2002)
(a) Test cross (b) Back cross
(c) Dihybrid cross (d) Monohybrid cross

475. Frameshift mutation occurs when: (AIIMS 2002)
(a) Base is deleted
(b) Base is added
(c) Base is deleted or added
(d) Anticodons are not present

476. Pure line breed refers to: (AIIMS 2002)
(a) Heterozygosity only
(b) Homozygosity only
(c) Heterozygosity and linkage
(d) Homozygosity and self-assortment

477. In the subsequent generation 25% of the population is lost. The process responsible will be: (VVMC Safdarjung 2001)
(a) Recessive lethal gene (b) Chasmotropic inheritance
(c) Polygenic inheritance (d) Quantitative inheritance

478. A normal man marries a colourblind female. Then the grandsons of F_2 generation would be: (VVMC Safdarjung 2001)
(a) All normal
(b) All colourblind
(c) All normal but carriers
(d) 50% normal and 50% carriers

479. If hybrid red flowered plants of pea are crossed back to pure red flowered parent, the progeny will show: **(MPPMT 2002)**
(a) All red flowered plants
(b) White flowered plants
(c) 50% red and 50% white flowered plants
(d) 3 red : 1 white flowered plants

***480.** There are three genes a, b, c; percentage of crossing over between a and b is 20%, b and c is 28% and a and c is 8%. What is the sequence of genes on the chromosome? **(CBSE 2002)**
(a) b, a, c (b) a, b, c
(c) a, c, b (d) None of these

481. Determination of sex-linked genes was first done by: **(MGIMS Wardha 2001)**
(a) Bridges (b) Morgan
(c) Mendel (d) None of these

482. In ABO blood groups the different blood groups are: **(Haryana PMT 2001)**
(a) Co-dominant (b) Dominant
(c) Recessive (d) Incomplete dominant

***483.** In a certain plant red colour flower (R) is dominant over white colour flower (r). When a heterozygous Rr plant is selfed, 64 offsprings are obtained. The number of white offsprings are: **(DPMT 2001)**
(a) 64 (b) 0
(c) 16 (d) 32

484. The blood types in man show: **(MPPMT 2002)**
(a) Quantitative characters (b) Qualitative characters
(c) Multiple alleles (d) Polygenic characters

485. Complete dominance is absent in: **(JIPMER 2002)**
(a) *Pisum sativum* (b) *Mirabilis jalapa*
(c) *Lathyrus odoratus* (d) *Oenothera lamarckiana*

486. Criss-cross inheritance is observed for genes present on: **(CET MH 2003)**
(a) Autosomes (b) Y-chromosome
(c) X-chromosome (d) X and Y chromosomes

487. Klinefelter's syndrome is: **(Jharkhand CECE 2003; CMC,Vellore 2003)**
(a) XO (b) XXX
(c) XXY (d) XXXY

488. Dihybrid cross explains: **(Jharkhand CECE 2003)**
(a) Law of dominance (b) Purity of gametes
(c) Independent assortment (d) Law of segregation

489. The probability of the male child of a haemophiliac father and normal mother, becoming haemophiliac is: **(Jharkhand CECE 2003)**
(a) 0% (b) 25%
(c) 50% (d) 100%

490. In a cross between individuals with genotypes TtRr, if the resulting number of offsprings is 16, identify the number of genotypes with TtRr and TtRR amongst them: **(EAMCET 2003)**
(a) 1 and 2 (b) 2 and 3
(c) 3 and 1 (d) 4 and 2

491. Phenomenon of crossing over in diploid organisms is responsible for: **(CET J&K 2003)**
(a) Linkage between genes
(b) Recombination between linked genes
(c) Segregation between genes
(d) Dominance of gene

492. Which of the following laws was discovered first by Mendel? **(CPMT 2003)**
(a) Law of dominance
(b) Law of segregation
(c) Law of independent assortment
(d) Law of sex determination

493. Haemophilia is rare in women because: **(BHU 2003)**
(a) It is recessive autosomal gene disorder
(b) Women ought to be homozygous for this gene
(c) They have only one X-chromosome
(d) They are more recessive to this disorder

494. The loss of one single chromosome creates a condition called: **(Orissa JEE 2003)**
(a) Trisomy (b) Nullisomy
(c) Monosomy (d) Haploid

495. Heterozygous purple flower is crossed with recessive white flower. The progeny has the ratio: **(DPMT 2003)**
(a) All purple (b) All white
(c) 50% purple, 50% white (d) 75% purple, 25% white

496. In *Melandrium*, the sex determination type is: **(Kerala PMT 2003)**
(a) XX-XY type (b) XX-XO type
(c) ZZ-ZW type (d) XY-XO type

497. Mendelism is related with: **(B.V. Pune 2003)**
(a) Heredity in living beings
(b) Meiosis during sexual reproduction
(c) Mutation in living organisms
(d) None of the above

498. The genes controlling the seven pea characters studied by Mendel are now known to be located on how many different chromosomes? **(CBSE 2003)**
(a) Six (b) Five
(c) Four (d) Seven

499. Which traits of garden pea studied by Mendel was a recessive feature? **(CBSE 2003)**
(a) Green seed colour (b) Green pod colour
(c) Round seed shape (d) Axial flower position

500. Genetic map is one that: **(CBSE 2003)**
(a) Shows the stages during the cell division
(b) Establishes various stages in gene evolution
(c) Establishes sites of the genes on a chromosome
(d) Shows the distribution of various species in a region

501. The linkage map of X-chromosome of fruitfly has 66 units, with yellow body gene (y) at one end and bobbed hair (b) gene at the other end. The recombination frequency between these two genes should be: **(CBSE 2003)**
(a) > 50% (b) ≤ 50%
(c) 100% (d) 66%

ANSWERS

1—c	2—c	3—b	4—c	5—d	6—b	7—d	8—a	9—c	10—b	11—b	12—b
13—c	14—d	15—b	16—b	17—d	18—b	19—c	20—c	21—d	22—b	23—d	24—c
25—b	26—d	27—b	28—c	29—b	30—a	31—c	32—b	33—d	34—c	35—b	36—c
37—d	38—b	39—c	40—c	41—c	42—d	43—b	44—d	45—b	46—c	47—b	48—b
49—c	50—b	51—c	52—a	53—b	54—b	55—a	56—b	57—b	58—b	59—c	60—c
61—b	62—b	63—b	64—c	65—b	66—c	67—b	68—c	69—b	70—c	71—c	72—c
73—a	74—d	75—c	76—b	77—b	78—d	79—b	80—a	81—a	82—b	83—c	84—d
85—c	86—d	87—c	88—a	89—d	90—b	91—b	92—b	93—c	94—d	95—c	96—b
97—d	98—d	99—d	100—	101—c	102—b	103—a	104—d	105—c	106—c	107—d	108—c
109—c	110—c	111—d	112—c	113—c	114—b	115—b	116—b	117—d	118—b	119—a	120—d
121—d	122—c	123—d	124—b	125—c	126—b	127—b	128—d	129—d	130—d	131—b	132—b
133—c	134—c	135—b	136—c	137—d	138—d	139—c	140—b	141—d	142—a	143—c	144—c
145—c	146—c	147—c	148—c	149—a	150—b	151—d	152—c	153—a	154—d	155—b	156—c
157—a	158—d	159—d	160—a	161—d	162—c	163—a	164—c	165—a	166—b	167—d	168—c
169—b	170—a	171—b	172—c	173—d	174—c	175—a	176—b	177—b	178—a	179—c	180—a
181—c	182—c	183—d	184—b	185—d	186—d	187—b	188—a	189—c	190—a	191—a	192—c
193—a	194—b	195—b	196—d	197—c	198—d	199—c	200—d	201—a	202—a	203—d	204—a
205—b	206—a	207—d	208—b	209—d	210—c	211—c	212—a	213—c	214—b	215—a	216—a
217—c	218—d	219—b	220—b	221—b	222—d	223—b	224—b	225—b	226—c	227—a	228—a
229—a	230—a	231—c	232—d	233—a	234—a	235—d	236—c	237—a	238—d	239—b	240—a
241—b	242—b	243—b	244—a	245—c	246—a	247—d	248—c	249—d	250—c	251—d	252—a
253—b	254—a	255—c	256—d	257—a	258—a	259—c	260—c	261—c	262—c	263—c	264—d
265—b	266—d	267—b	268—c	269—b	270—c	271—a	272—d	273—d	274—b	275—b	276—c
277—c	278—a	279—b	280—d	281—b	282—b	283—a	284—d	285—b	286—c	287—d	288—b
289—b	290—b	291—c	292—d	293—b	294—b	295—b	296—d	297—d	298—c	299—d	300—b
301—c	302—c	303—b	304—d	305—c	306—a	307—b	308—d	309—a	310—d	311—d	312—b
313—d	314—c	315—a	316—a	317—d	318—a	319—c	320—a	321—c	322—a	323—b	324—c
325—a	326—c	327—d	328—b	329—a	330—a	331—b	332—c	333—b	334—c	335—d	336—c
337—a	338—d	339—a	340—d	341—a	342—a	343—d	344—a	345—c	346—c	347—c	348—a
349—c	350—d	351—c	352—c	353—b	354—a	355—d	356—a	357—c	358—c	359—c	360—d
361—a	362—b	363—a	364—b	365—b	366—a	367—d	368—d	369—c	370—d	371—b	372—b
373—b	374—a	375—d	376—c	377—a	378—b	379—a	380—d	381—c	382—d	383—b	384—d
385—b	386—a	387—b	388—c	389—d	390—a	391—c	392—c	393—a	394—b	395—d	396—d
397—b	398—d	399—a	400—c	401—b	402—a	403—a	404—b	405—a	406—a	407—d	408—b
409—a	410—b	411—b	412—a	413—b	414—c	415—b	416—b	417—b	418—a	419—c	420—d
421—b	422—b	423—a	424—b	425—b	426—d	427—a	428—d	429—c	430—c	431—a	432—d
433—a	434—b	435—c	436—a	437—b	438—d	439—a	440—b	441—d	442—a	443—b	444—c
445—c	446—d	447—a	448—c	449—c	450—d	451—c	452—a	453—c	454—c	455—c	456—a
457—c	458—c	459—b	460—c	461—c	462—a	463—d	464—b	465—d	466—a	467—a	468—d
469—b	470—b	471—b	472—b	473—c	474—a	475—c	476—b	477—a	478—a	479—a	480—a
481—b	482—a	483—c	484—c	485—b	486—c	487—c	488—c	489—a	490—d	491—b	492—b
493—b	494—c	495—c	496—a	497—a	498—c	499—a	500—c	501—d			

EXPLANATION OF SELECTED QUESTIONS (*)

29. The condition where only one gene or allele of allelic pair is present, is called hemizygous condition (*e.g.*, X^hX).

30. When a pure tall plant is reared in poor soil, it becomes dwarf phenotypically (not genotypically), *i.e.*, environmental variation (not hereditary variation).

57. Number of linkage group in prokaryotes (Cyanophyceae) is 1 (as there is single naked chromosome, *i.e.*, $n = 1$)

80. There is apparent absence of crossing over in males of *Drosophila*.

124. Cytoplasmic or extranuclear inheritance is maternal (as egg provides more cytoplasm).

142. Crossing of two organisms of unlike genetic constitution leads to hybrid vigour (Superiority of hybrid over its parents) or heterosis.

147. As 'Y' chromosome is 1 in males, so even a recessive gene present on it (hemizygous condition) produces its effect. Y-located gene is called holandric gene.

178. Borlaug is Mexican wheat breeder whereas M.S. Swaminathan and B.P. Pal are famous wheat breeders of India.

181. Wild species are disease resistant and thus disease resistance can be introduced in cultivated forms from wild relatives by hybridization.

187. Seven traits selected by Mendel in pea are now known to be located on only 4 chromosomes, *i.e.*, on 1,4,5,7 chromosomes.

201. When two dominants or recessives enter from the same parent, they try to remain together (Coupling) and when two dominants or recessives enter from different parents, they try to remain separate (repulsion).

238. In sweet pea, C and P are complementary factors, *i.e.*, flower colour is produced when both these dominants are present together.

267. $(2n + 1)$ genetic constitution is called trisomic. Here in plant with constitution AABBBCCDD, an extra chromosome is present.

369. If a character is transmitted from father to his sons and then to grandson only, it means it is located on Y-chromosome (Inheritance of Y-linked genes).

394. A typical plant cell is $2n$ (sporophytic) and thus there are 2 haploid sets of chromosomes (2 genomes).

397. Normally blood coagulation occurs after 2–8 minutes of injury but in haemophilia, coagulation occurs after 30 minutes to 24 hrs. (*i.e.*, delayed coagulation).

404. It is a cross between carrier woman (XX^c) and colourblind (X^cY) man.

405. 8 types of gametes are produced by a trihybrid.

407. It is a cross between X^hY and XX.

414. It is tetrahybrid and thus number of gametes produced is $2^4 = 16$.

420. 4 dwarf in F_2 generation (3 dwarf yellow and 1 dwarf green).

422. Every time there is 50% possibility of girl and 50% of boy as egg (X) may be fertilized by sperm (X) or sperm (Y).

447. As discontinuous variations are discrete and distinct variations and these arise by sudden genetic changes, *i.e.*, mutations.

458. As F_1 hybrid of this cross is having intermediate length of the internodes, hence it is a case of incomplete dominance.

461. AABbCC is a monohybrid and selfing of monohybrid leads to 3 : 1 phenotypic ratio in F_2 generation.

462. Sickle-cell anaemia, a hereditary disease, is an example of pleiotropy (ability of a gene to have many effects).

469. A normal woman whose father was colourblind, will be carrier of this disease. Hence it is a cross between XX^c and X^cY.

480. Cross over frequency or percentage of crossing over is directly proportional to distance between the genes.

483. Selfing of monohybrid results in 3 : 1 phenotypic ratio.

TEST PAPER Unit–3

1. DNA is unique molecule as it can:
(a) Form multipolymer
(b) Come apart and reform complexes
(c) Replicate itself
(d) Withstand very high temperature

2. ATP molecule is structurally most similar to a molecule of:
(a) RNA nucleotide (b) DNA nucleotide
(c) Amino acid (d) Fatty acid

3. Which of the following molecules makes regular movements from nucleus to the cytoplasm?
(a) RNA (b) DNA (c) Glycogen (d) Cholesterol

4. Chargaff estimated the base composition of human sperm and found adenine 31% and guanine 19%. What is the likely quantity of cytosine in the DNA of a human somatic cell?
(a) 19% (b) 38% (c) 31% (d) 62%

5. DNA differs from RNA in:
(a) Nature of sugar (b) Nature of purines
(c) Nature of sugar and pyrimidines both
(d) All of the above

6. Which of the following are extrinsic information molecules?
(a) RNA (b) m-RNA (c) Hormones (d) Enzymes

7. m-RNA is a polymer of:
(a) Deoxyribonucleotides (b) Ribonucleosides
(c) Ribonucleotides (d) Deoxyribonucleosides

8. Number of base pairs in one turn of Z-DNA helix is:
(a) 10 (b) 11 (c) 12 (d) 15

9. Extranuclear DNA is found in:
(a) Chloroplast (b) Golgi apparatus
(c) Ribosomes (d) E.R.

10. The process by which genetic information of DNA of nucleus passes to m-RNA is called:
(a) Transcription (b) Translocation
(c) Translation (d) Replication

11. DNA strands are bound by:
(a) Hydrogen bonds (b) Phosphodiester bonds
(c) Ionic bonds (d) Covalent bonds

12. Diameter of DNA is about:
(a) 20 Å (b) 24 Å (c) 30 Å (d) 34 Å

13. Distance between two bases of a DNA molecule is:
(a) 3.4 Å (b) 4.3 Å (c) 4.43 Å (d) 6.8 Å

14. 'One gene one enzyme' concept of enzyme action was given by:
(a) Lederberg and Tatum (b) Zinder and Lederberg
(c) Beadle and Tatum (d) Kornberg and Tatum

15. 'Operon model' as a controlling mechanism in bacteria was given by:
(a) Nirenberg (b) Kornberg
(c) Holley, R (d) Jacob and Monod

16. Crossing over is advantageous as it brings about:
(a) Linkage (b) Variation (c) Inbreeding (d) Stability

17. *In vitro* synthesis of DNA was carried out by:
(a) Watson and Crick (b) Nirenberg
(c) Kornberg (d) Khorana

18. A riboside is:
(a) N. base + phosphate (b) Ribose + phosphate
(c) Ribose + sugar + phosphate
(d) Ribose + N-base

19. The wrong statement about nucleic acids is:
(a) DNA is single stranded in some viruses
(b) One turn of Z-DNA has 12 bases
(c) RNA is double stranded sometimes
(d) Length of one helix is 45 Å in B-DNA and 34 Å in Z-DNA

20. Which of the following is known as blueprint of information?
(a) RNA (b) DNA
(c) Proteins (d) None of these

21. Translation means:
(a) DNA synthesis (b) RNA synthesis
(c) Protein synthesis (d) Assembly of ribosomes

22. The experimental material used in studies on discovery of replication of DNA, has been:
(a) *E. coli* (b) *Neurospora crassa*
(c) *Drosophila melanogaster* (d) *Mycococcus condisans*

23. When DNA is isolated and heated at 82–90°C:
(a) DNA structure is stabilized
(b) Fragmentation occurs
(c) The weak H-bonds break and two strands uncoil and separate
(d) Nothing occurs

24. Cytoplasmic DNA constitutes what percentage of total DNA in a cell?
(a) 95–99% (b) 45–50% (c) 65–75% (d) 1–5%

25. 'Central dogma' of molecular biology includes:
(a) Transcription (b) Transfusion
(c) Translation (d) Both (a) and (c)

26. m-RNA is formed:
(a) From DNA in nucleus (b) From DNA in cytoplasm
(c) From ribosomes on E.R. (d) By free ribosomes

27. In replication of DNA, the Okazaki segments on lagging strand are joined together by:
(a) DNA polymerase (b) DNA-ligase
(c) Helicase (d) Unwindase

28. The part of DNA which varies among DNA molecule is:
(a) Its nitrogenous bases (b) Its sugars
(c) Its phosphates (d) None of these

29. 'Wobble effect' is:
(a) Control of protein synthesis in eukaryotes
(b) Degeneracy of genetic code
(c) Lack of precision with regard to third base in the codon and anticodon
(d) Instability of DNA when heated

30. The phenotypic ratio of a dihybrid back cross is:
(a) 1 : 1 (b) 1 : 1 : 1 : 1 (c) 1 : 2 : 1 (d) 3 : 1

31. Which of the following is exception to Mendel's law of dominance?
(a) *Mirabilis jalapa* (b) *Antirrhinum majus*
(c) Both (a) and (b) (d) None of these

32. In a cross AABB × aabb (when the two dominants enter from the same parent), the tendency of genes will be of:
(a) Coupling (b) Repulsion
(c) Both (a) and (b) (d) None of these

33. Replacement of one purine by another purine in gene mutation is called:
(a) Transition (b) Transversion
(c) Inversion (d) Translocation

34. Exchange of parts between non-homologous chromosomes is called:
(a) Crossing over (b) Duplication
(c) Inversion (d) Translocation

35. Degeneracy in genetic code means:
(a) Multiple coding system
(b) Non-overlapping genetic code
(c) Commaless genetic code
(d) Non-ambiguous genetic code

36. Barbara McClintock, a Nobel Prize winner is associated with the discovery of:
(a) Mobile genetic elements in maize
(b) Jumping genes
(c) Transposable genetic elements
(d) All of the above

37. A gene producing multiple effect is called:
(a) Pleiotropic gene (b) Split gene
(c) Complementary gene (d) Supplementary gene

38. Functional unit of gene is called:
(a) Cistron (b) Muton
(c) Recon (d) None of these

39. Genetic material in retroviruses is:
(a) Double stranded DNA (b) Single stranded RNA
(c) RNA (d) None of these

40. Discovery of enzyme reverse transcriptase, which is capable of reverse transcription was made by:
(a) Khorana (b) Kornberg
(c) Baltimore, Temin and Dulbecco
(d) Lederberg and Kornberg

41. F_2 phenotypic ratio in the interaction of supplementary factors is:
(a) 9 : 7 (b) 9 : 3 : 4 (c) 12 : 3 : 1 (d) 13 : 3

42. Crossing of albino maize plant as female with normal green plant as male produces all albino plants in progeny. This indicates:
(a) Albino character is dominant over green
(b) Mutation occurs in green plastids of male parent
(c) There is cytoplasmic (maternal) inheritance in plastids
(d) Chromosomal aberration occurs

43. Term 'anticodon' is related with:
(a) DNA (b) m-RNA
(c) t-RNA (s-RNA) (d) r-RNA

44. Semiconservative mode of DNA replication was discovered by:
(a) Griffith (b) Beadle and Tatum
(c) Meselson and Stahl (d) None of these

45. Double helix model of DNA was given by Watson and Crick in 'Nature' in:
(a) 1930 (b) 1953 (c) 1963 (d) 1978

46. Crossing of AaBbCc with aabbcc results in phenotypic ratio:
(a) 1 : 1 : 1 : 1 (b) 9 : 3 : 3 : 1
(c) 1 : 1 : 1 : 1 : 1 : 1 (d) 1 : 1 : 1 : 1 : 1 : 1 : 1 : 1

47. Number of nitrogen atoms present in a single purine base is:
(a) 3 (b) 4 (c) 5 (d) 6

48. A plant with N = 10, will be having what number of chromosomes in its trisomic?
(a) 10 (b) 11 (c) 20 (d) 21

49. Genes producing independent dominant effects in heterozygous condition are named as:
(a) Supplementary (b) Complementary
(c) Epistatic (d) Co-dominant

50. Purine base characteristic of RNA is:
(a) Uracil (b) Thymine
(c) Both (a) and (b) (d) None of these

51. First triplet codon discovered was:
(a) AUG (b) GUG (c) UUU (d) UAG

52. Restriction endonucleases are utilized in genetic engineering as:
(a) Molecular build up at nucleotides
(b) Molecular degradation to DNA break up
(c) Molecular scalpels for cutting DNA at specific sites
(d) Molecular cement for combining DNA bits into long chains

53. The codon for anticodon 3′ UUA 5′ is:
(a) 3′ AAU 5′ (b) 5′ AAU 3′ (c) 5′ UAA 3′ (d) 3′ UAA 5′

54. Recombinant DNA molecules were first of all synthesized by Paul Berg using DNA of:
(a) TMV and *Salmonella*
(b) Virus SB-40 and *E. coli*
(c) Influenza virus and *Diplococcus* bacterium
(d) TMV and *Agrobacterium tumefaciens*

55. A technique used to amplify a specific DNA fragment of interest is:
(a) Molecular probe technique
(b) Blotting pattern technique
(c) Polymerase chain reaction
(d) DNA finger-printing

ANSWERS

1—c	2—a	3—a	4—b	5—c	6—b	7—c	8—c	9—a	10—a	11—a	12—a
13—a	14—c	15—d	16—b	17—c	18—d	19—d	20—b	21—c	22—a	23—c	24—d
25—d	26—a	27—b	28—a	29—c	30—b	31—c	32—a	33—a	34—d	35—a	36—d
37—a	38—a	39—c	40—c	41—b	42—c	43—c	44—c	45—b	46—d	47—b	48—d
49—d	50—d	51—c	52—c	53—b	54—b	55—c					

UNIT-3

ASSERTION AND REASON TYPE QUESTIONS

In the questions given below, two statements—an Assertion (A) and a Reason (R) are given. Give the appropriate response as:

(a) *If both A and R are true and R is the correct explanation of A.*
(b) *If both A and R are true but R is not the correct explanation of A.*
(c) *If A is true but R is false.*
(d) *If both A and R are false.*
(e) *If A is false and R is true.*

1. A: DNA is the genetic material of most of the organisms.
   R: Transformation experiment or Griffith effect is the strongest evidence in favour of DNA as genetic material.
2. A: DNA is the hereditary material.
   R: All the cells of organism are having constant amount of DNA.
3. A: In transformation experiment, R-type bacteria are transformed or changed into S-type bacteria.
   R: DNA passed from heat killed S-type bacteria into R-type bacteria and changed R-type into S-type bacteria.
4. A: RNA is the genetic material in plant viruses.
   R: When RNA of TMV is made to infect tobacco plant, it causes tobacco mosaic disease.
5. A: DNA is macromolecule of high molecular weight.
   R: Amino acids are monomeric units of DNA.
6. A: DNA consists of two complementary polynucleotide chains.
   R: In two polynucleotide chains, A pairs with T and G pairs with C.
7. A: Constant diameter of DNA double helix is 20 Å.
   R: In two polynucleotide chains forming DNA, purines always pair with pyrimidines and *vice-versa.*
8. A: In a DNA molecule, A-T rich portions melt before G-C rich portions.
   R: In between A and T, there are 2 H-bonds whereas in between G-C, there are 3 H-bonds.
9. A: t-RNA is called adopter-RNA or adoptive RNA.
   R: Function of t-RNA is to carry genetic information present in DNA inside nucleus to cytoplasm for protein synthesis.
10. A: m-RNA is short-lived RNA.
    R: Formation of m-RNA from DNA is called transcription.
11. A: r-RNA are smallest molecules of RNA.
    R: Most studied type of RNA is r-RNA.
12. A: DNA synthesis *in vitro* was done by A. Kornberg.
    R: A. Kornberg discovered DNA-polymerase enzyme.
13. A: In prokaryotic cells, three distinct types of RNA polymerases are present.
    R: RNA-polymerase in *E.coli* consists of five polypeptide chains.
14. A: In prokaryotes, initiating amino acid methionine is formylated.
    R: t-RNA$_m$*met* carries methionine amino acid to site of protein synthesis in prokaryotes.
15. A: Formation of DNA on RNA template is called Teminism.
    R: Reverse transcription discovery proved to be useful in cancer studies.
16. A: Operon model was given by Jacob and Monod for regulation of protein synthesis in eukaryotes.
    R: Operon is a set of structural genes and associated control genes.
17. A: Lac operon given by Jacob and Monod is repressible operon.
    R: The system of regulation in lac operon is always a negative control.
18. A: DNA segments which can join with other DNA segments completely unrelated are called transposons or jumping genes.
    R: These DNA segments are transposable and may be present on different places on main DNA.
19. A: Exons and introns are present in split genes.
    R: Introns are the information pieces of split genes.
20. A: Restriction endonucleases and ligase are the main tools of genetic engineering.
    R: Restriction endonuclease cuts the H-bonds of DNA.
21. A: Restriction enzymes are present in different bacteria.
    R: Sequences recognized by restriction enzymes are 4 to 8 nucleotides long.
22. A: Restriction endonucleases are called chemical scissors.
    R: These enzymes cut DNA at precise base sequences with surgical neatness producing defined fragments.
23. A: Polymerase chain reaction is nicknamed as 'People choice reaction'.
    R: This technique is used to amplify a specific DNA fragment of interest.
24. A: PCR takes place in Eppendorf tube.
    R: Taq polymerase enzyme is used in place of ordinary DNA polymerase in PCR.
25. A: Variations are of two types, *i.e.,* hereditary variations and environmental variations.

R: In organisms without sexual reproduction, hereditary variations are greatly absent.

26. A: Common garden pea is experimental material of Mendel.
R: Pea is having well defined differentiating characters, having bisexual flowers and is predominantly self-fertilized.

27. A: *Mirabilis jalapa* is an example of blending inheritance or incomplete dominance.
R: When a red flowered variety of this plant is crossed with white flowered variety, pink flowers are produced in F_1 generation.

28. A: Lethal factors cause death of organism only in homozygous condition.
R: Lethal factors are present in recessive state.

29. A: Tendency of parental combinations to remain together is called crossing over.
R: Crossing over provides a proof in favour of linear arrangement of genes on chromosomes.

30. A: Number of linkage groups in *Pisum sativum* is 7.
R: Number of linkage groups in an organism is equal to its haploid number of chromosomes.

31. A: Cross over frequencies are used in formation of linkage maps.
R: Recombination frequencies are directly proportional to distances between genes.

32. A: Organisms lacking one complete chromosome are called monosomics.
R: Down's syndrome is an example of monosomy.

33. A: Wheat is nowadays considered to be an example of segmental polyploidy.
R: Three genomes A, B and D of wheat show homocologous relationship.

34. A: Transversions are more common in nature than transitions.
R: When purine is replaced by pyrimidine and *vice-versa*, such base pair replacements are called transitions.

35. A: Frameshift mutations cannot be changed to normal or wild type.
R: UV-rays cause frameshift mutations.

36. A: Plasmon is the totality of hereditary material present in cytoplasm.
R: Cytoplasmic inheritance is mainly paternal.

37. A: *Neurospora* is commonly called water mould.
R: *Neurospora* belongs to class basidiomycetes of fungi.

38. A: Crossing over occurs at 4-stranded stage.
R: Tetrad analysis in *Neurospora* has shown 2 : 2 : 2 : 2 arrangement.

39. A: The t-RNA molecules possess anticodons. (AIIMS 1996)
R: It reads the message in the form of codon.

40. A: Plasmids are single stranded extra-chromosomal DNA. (AIIMS 1997)
R: Plasmids are possessed by eukaryotic cells.

41. A: The genetic complement of the organism is known as genotype. (AIIMS 1999)
R: Genotype is the type of hereditary properties of an individual.

42. A: Phenylketonuria is a recessive hereditary disease caused by the body's failure to breakdown phenylpyruvic acid into hydroxy-phenylpyruvic acid. (AIIMS 2000)
R: It results in accumulation of phenylpyruvic acid.

43. A: Haemophilia is a sex-linked disease. (AIIMS 2001)
R: It is due to presence of a recessive gene on X-chromosome

44. A: The m-RNA attaches itself to the ribosome via its 3′ end. (AIIMS 2002)
R: The m-RNA has F-capsular nucleotide and bases of lagging sequence.

ANSWERS

1. (a) **2.** (a) **3.** (a) **4.** (a) **5.** (c) **6.** (a) **7.** (a) **8.** (a) **9.** (c) **10.** (b)
11. (d) **12.** (a) **13.** (c) **14.** (c) **15.** (b) **16.** (c) **17.** (d) **18.** (a) **19.** (c) **20.** (c)
21. (b) **22.** (a) **23.** (a) **24.** (b) **25.** (b) **26.** (a) **27.** (a) **28.** (a) **29.** (c) **30.** (a)
31. (a) **32.** (c) **33.** (a) **34.** (d) **35.** (d) **36.** (c) **37.** (d) **38.** (a) **39.** (b) **40.** (c)
41. (a) **42.** (a) **43.** (a) **44.** (d)

UNIT-4

- Bacteria, Mycoplasma and Viruses
- Algae
- Fungi and Lichens
- Bryophyta
- Pteridophyta
- Gymnosperms
- Test Paper—Unit-4
- Assertion and Reason Type Questions—Unit-4

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9

Bacteria, Mycoplasma and Viruses

- Bacteria—Historical, Characteristic features, Gram –ve and Gram +ve bacteria, Distribution and habitat, Form and morphology, Structure of bacterial cell, Nutrition, Reproduction, Importance of bacteria; Characteristic features of *E. coli*, Spirochaetes, Actinomycetes, Archaebacteria, Cyanobacteria
- Mycoplasma—Historical, Characteristic features, Culture of mycoplasma, Structure, Difference between L-form bacteria and mycoplasma, Reproduction, Evolutionary significance, Diseases caused by mycoplasma
- Viruses—Historical, Characteristic features, Classification, Nomenclature, Morphology and structure, TMV, Influenza virus, Bacteriophages, Mycophages, Viroids, Prions, Virion, Interferons, Diseases caused by viruses

BACTERIA

Anton van Leeuwenhoek (1683), a Dutch, observed small or tiny animalcules in sewage water, saliva and tooth scum under his crude microscope and these animalcules were later known as bacteria.

Ehrenberg (1829) gave the term **bacterium.**

Linnaeus placed them under genus vermes. **Nageli** classified bacteria under **Schizomycetes.**

- **Louis Pasteur** gave **germ theory of diseases** as he reported that certain diseases in plants and animals are caused by them.
- **Robert Koch** first of all cultured bacteria.
- **John Lister** started antiseptic surgery using carbolic acid as disinfectant.

The branch which deals with study of bacteria is known as **bacteriology. Anton van Leeuwenhoek is the father of bacteriology.**

Bacteria are prokaryotic organisms without well defined organelles like mitochondria, Golgi bodies, E.R., etc.

Bacteria are oldest, most abundant and simplest organisms and these were abundant for over 2 billion years before the appearance of eukaryotes in the world. These were responsible for creating the properties of atmosphere and soil. Further these bacteria make life on earth possible as they perform integral functions as decomposers of organic materials.

Characteristic features of bacteria

(1) Bacteria contain both types of nucleic acids, *i.e.*, DNA and RNA. True nucleus with well defined nuclear membrane is absent, but nuclear material is present in the centre of cell which is not surrounded by any membrane. This primitive type of nucleus is known as **nucleoid** or **genophore** or **incipient nucleus.**

N acamic acid mino

(2) Two major types of cell division, *i.e.*, mitosis and meiosis are absent in bacteria, although in *Bacillus megatherium*, mitosis is present.

(3) Ribosomes are of 70-S type (50S + 30S).

(4) Well defined organelles like mitochondria, Golgi bodies, E.R., etc., are absent.

(5) On the plasma membrane of bacteria, there are present some circular coiled bodies, which are infoldings of plasma membrane, known as **mesosomes.** These mesosomes contain respiratory enzymes like oxidases and dehydrogenases, etc., and thus the main function of mesosomes is that they help in respiration. Secondly, these are present at mid point, so help in equal distribution of nuclear material during binary fission.

(6) In the cell wall of bacteria, there are present two important **sugar derivatives** which are not present anywhere else, *i.e.*, **N-acetyl glucosamine** (NAG) and **N-acetyl muramic acid** (NAM), besides α-alanine, d-alanine, glutamic acid and diaminopimelic acid.

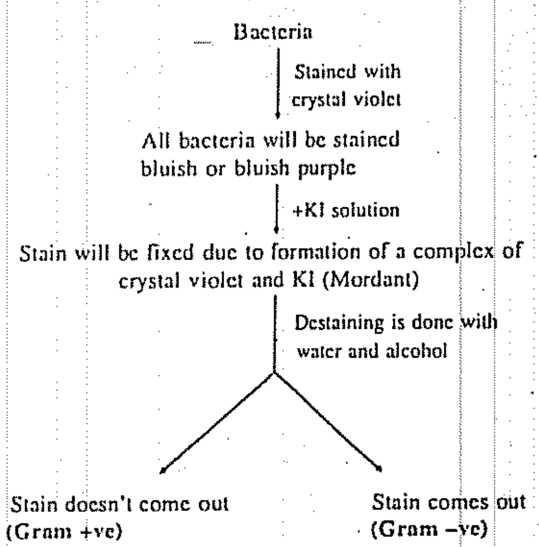
(7) Chlorophyll-a and b are not present in bacteria, although bacteriochlorophyll or chlorobium chlorophyll may be present. Thus chloroplasts are absent and chromatophores may be present.

So bacteria are **prokaryotes without chlorophyll-a and b.**

Gram-negative and Gram-positive bacteria

The technique of staining bacteria was given by a Dutch microbiologist **Christian Gram** and this technique is known as **Gram Staining Technique.** On the basis of this Gram staining, bacteria are of 2 types:

(i) Gram +ve bacteria
(ii) Gram –ve bacteria


Bacteria
Stained with crystal violet
All bacteria will be stained bluish or bluish purple
+KI solution
Stain will be fixed due to formation of a complex of crystal violet and KI (Mordant)
Destaining is done with water and alcohol
Stain doesn't come out (Gram +ve)
Stain comes out (Gram –ve)

In the cell wall of Gram +ve bacteria, both horizontal and vertical peptide linkages are present, due to which mesh is dense and hence the stain doesn't come out. Further outer layer of cell wall of Gram +ve bacteria is made of teichoic acid.

In the cell wall of Gram –ve bacteria, either horizontal or vertical peptide linkage are present, due to which mesh is loose and hence stain comes out. Further outermost layer of cell wall of Gram –ve bacteria is made of **lipopolysaccharides.** lipid + sugars.

Distribution and habitat

Bacteria are cosmopoliton in distribution and are **ubiquitous** (every where). They occur in water, soil, air, animals, plants, in snow (upto –190°C) and also in hot water streams (upto 78°C).

Form and morphology of bacteria

Bacteria are small and simple plants. General length is 2 to 5 μ. (Although some forms may be upto 60 μ).

- Smallest known bacterium is *Dialister pneumonsintes* (0.15–0.3 μ).
- Largest known bacterium is a recently discovered bacterium *Epulopiscium fishelsoni* which is 0.3 mm long, *i.e.*, as large as a small hyphen (earlier *Bacillus buschili* in cockroach and *Spirillum volutans* were considered to be the largest bacteria).

Shapes of bacteria

Bacteria are of the following shapes:

(1) Rounded form or Coccus (Derived from the Greek word *kokkos* meaning particle).
Smallest bacteria are **rounded or coccus forms.**
  - (a) **Micrococcus:** When coccus form occurs singly.
  - (b) **Diplococcus:** When coccus forms occur in group of two.
  - (c) **Streptococcus:** When coccus forms form a chain.
  - (d) **Staphylococcus:** When coccus forms form a structure like a bunch of grapes.
  - (e) **Sarcinae:** When coccus forms form cubes of 8, 64 or more bacteria.

(2) **Rod shaped bacteria or Bacillus forms:** Bacillus forms generally occur singly but in *Bacillus anthracis*, chain of bacillus forms occurs.

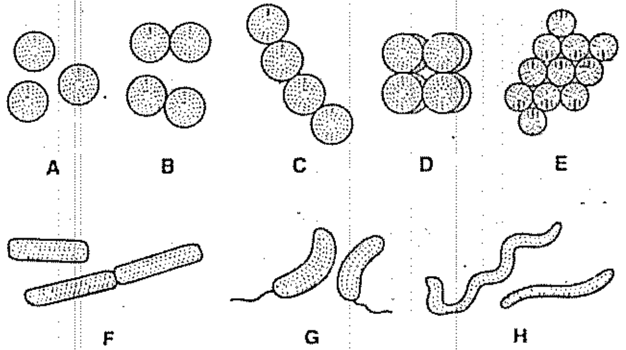


Fig. 9.1. Different shapes of bacteria: A. Micrococcus B. Diplococcus C. Streptococcus D. Sarcinae E. Staphylococcus F. Bacillus G. Vibrio H. Spirillum.

(3) **Comma shaped bacteria or Vibrio forms.**

(4) **Spiral shaped or Spirillum.**

Classification of bacteria on the basis of flagellation

Bacteria are of the following types on the basis of flagellation:

(1) **Monotrichous:** When single flagellum occurs at one end only, *e.g.*, *Pseudomonas*, *Thiobacillus*, *Vibrio cholerae*, *Xanthomonas citri*.

(2) **Lophotrichous:** When a group of flagella is present at one end only, *e.g.*, *Spirillum volutans*.

(3) **Amphitrichous:** When single or group of flagella is present at both the ends, *e.g.*, *Nitrosomonas*.

(4) **Peritrichous:** When flagella are present all over the surface of bacteria, *e.g.*, *E. coli*, *Salmonella*, *Proteus vulgaris*.

(5) **Atrichous:** When flagella are absent, *e.g.*, *Pasteurella pestis*, *Lactobacillus*.

monotrichous
Teichoic acid

MCQ

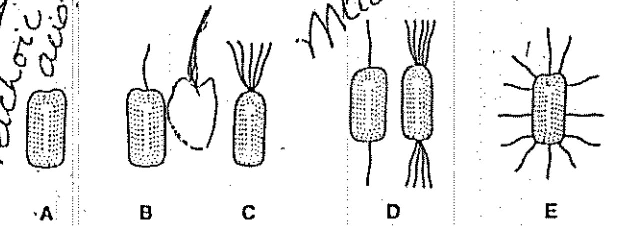


Fig. 9.2. Different types of bacteria on the basis of flagellation: A. Atrichous B. Monotrichous C. Lophotrichous D. Amphitrichous E. Peritrichous

Structure of bacterial cell

Whatever may be the shape of bacterial cell, the general structure remains the same. On outer side there are present **wall** layers and inner to these layers, there is present **matrix** or **protoplasm** with different structures and inclusions.

(A) Wall layers

From outside to inside, following wall layers are present:

(i) **Capsule or Slime layer:** In many bacteria, on outer surface, there is present capsule or slime layer. When components of this layer are compactly arranged, it is called capsule and when components are loosely arranged, it is called slime layer.

- Presence or absence of capsule is genetically fixed.
- Capsule or slime layer is made of **polysaccharides** and **amino acids.**
- Capsulated bacteria form smooth colonies and are known as **S-type bacteria** which are **highly virulent.**
- Non-capsulated bacteria form rough colonies and are known as **R-type bacteria.**

Functions of capsule:

(i) It acts as osmotic barrier.

(ii) During food scarcity it acts as reserve food material after digestion.

(ii) **Cell wall:** Inner to capsule or slime layer, is present cell wall. Cell wall is made of **polysaccharides, proteins and lipids.**

- In the cell wall of bacteria there are 2 important sugar derivatives which are not found anywhere else, *i.e.*, NAG, NAM (N-acetyl glucosamine and N-acetyl muramic acid), besides (1)α-alanine, (2)d-alanine, (3)glutamic acid and (4)di-aminopimelic acid.
- One of the unique components of cell wall of bacteria is **peptidoglycan** or **mucopeptide** or **murein** (made of mucopolysaccharide + polypeptide). In peptidoglycan, NAG and NAM are joined by short peptide chains or cross bridges of amino acids. The cell walls of Gram +ve bacteria contain 60–90% peptidoglycan whereas cell walls of Gram –ve bacteria contain about 10% peptidoglycan.
- Outer layer of cell wall of Gram –ve bacteria is made of **lipopolysaccharides** and of Gram +ve bacteria, of **teichoic acid.** Cell wall of Gram –ve bacteria is thin (10–15 nm) and hard and is not destroyed by Penicillin, whereas cell wall of Gram +ve bacteria is thick (25–30 nm) and is destroyed by Penicillin. Further, cell wall of Gram –ve bacteria is less homogeneous, more complex and multilayered. Lipids (including phospholipids, lipopolysaccharides and lipoproteins) make up 80–85% of the total cell wall. The cell wall of Gram +ve bacteria is more homogeneous and single layered and amorphous. Lipids are almost absent. Presence of lipopolysaccharides in cell wall of Gram –ve bacteria makes them pathogenic.

The important **function** of cell wall is to provide definite shape to the cell.

(iii) **Plasma membrane or Cell-membrane:** Inner to cell wall is present plasma membrane. Plasma membrane is having typical tripartite structure (3-layered structure).

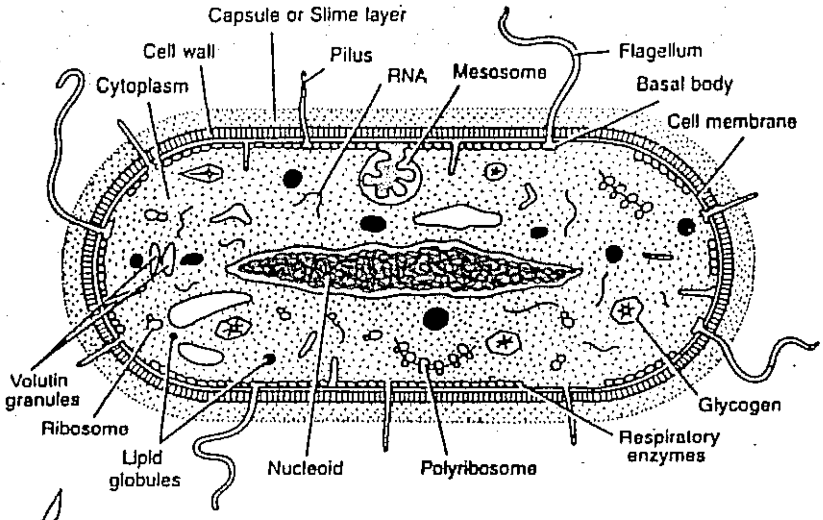


Fig. 9.3. Structure of bacterial cell

- Sterols are altogether absent in the cell membrane of bacteria.
- Plasma membrane is selectively permeable or differentially permeable.
- On the plasma membrane generally at mid point, there are present some circular coiled bodies called **mesosomes.** If plasma membrane is stretched then mesosomes disappear. So mesosomes are simply **infoldings of plasma membrane.** Mesosomes contain respiratory enzymes like **oxidases and dehydrogenases** and hence they help in **respiration.** Hence mesosomes are also known as **"mitochondria of bacterial cell"** or **chondrioides.** Secondly, as mesosomes are present at mid point, so they help in equal distribution of nuclear material during binary fission.

(iv) **Flagella:** There may be one or more flagella on the bacterial cell. Each flagellum is 4–5 μ in length and arises from a basal granule called **blepharoplast.** Flagellum is made up of **flagellin** protein.

- Typical (9 + 2) pattern of flagellum structure is **absent** in bacteria. But it is made up of one or three **α-helical strands.** Immunologically flagella provide **H-antigens.**

These are organs of **motility.**

(v) **Fimbriae or Pilli:** Besides flagella, some tiny or small hair-like outgrowths are present on bacterial cell surface. These are called **pilli** and are made of **pillin** protein. These are present in almost all Gram –ve bacteria and few Gram +ve bacteria. These are of 8 types: I, II, III, IV, V, VI, VII and F types.

- I and F are called **sex pilli.**

Function: They form conjugation tube during conjugation (2.5 μ in diameter). Secondly they help in attachment with other cells, *i.e.*, **agglutination or clump formation.**

(B) Matrix

Inner to wall layers, there is present matrix or protoplasm. It contains many structures and some inclusions like:

Nucleoid or Genophore: In the centre of the bacterial cell, there is present nuclear material (DNA) without any nuclear membrane. DNA in bacteria is **double helical and circular.** Guanine, cytosine (G, C) contents in DNA are lesser than adenine and thymine (A, T) contents. DNA is surrounded by some typical proteins (polyamines) but not histone proteins. Histones (basic proteins) are altogether absent in bacteria. This incipient nucleus or **primitive nucleus** is named as **nucleoid or genophore** (sometimes called single naked chromosome).

- Besides this nuclear DNA, there is some **extranuclear or extrachromosomal DNA,** which is known as plasmid. The plasmids are small, circular, double-stranded DNA molecules that are separate from main bacterial chromosome and replicate independently. The term plasmid was given by Lederberg (1952).
- Plasmids are having independent existence (don't attach to main or nuclear DNA).

(1) **F-Factor or fertility factor:** Which is responsible for transfer of genetic material.

(2) **R-factor or resistance factor:** It provides resistance against drugs.

(3) **Colicinogenic factor:** Which produces 'colicines' which kill other bacteria (other than which produce these colicines).

Episomes: The term episome is applied to extranuclear **genetic material which may remain in integrated or free state,** *e.g.,* **F-factor, temperate phage,** etc.

○ All plasmids are episomes but all episomes are not plasmids.

Ribosomes: Ribosomes are evenly distributed in the matrix. Ribosomes are of 70-S type (50 S + 30 S).

- Ribosomes are the seat of protein synthesis and ribosomes are made of r-RNA and protein.

Granules: There are granules of different types, *e.g.:*

(a) **Fatty acids granules or lipid granules or polybetahydroxy butyric acid granules.**

(b) **Volutin granules:** These are so called because they were first reported in *Spirillum volutans* bacteria.

These are larger in size and are chemically **polymetaphosphate** granules.

(c) **Glycogen and sulphur granules** are also present.

- In old bacterial cells, vacuoles may also be present besides some gases like H_2S, CO_2.
- In some photosynthetic bacteria simple chromatophores are present which contain **bacteriochlorophyll or chlorobium chlorophyll,** besides accessory pigments called **carotenoids.**

Nutrition in bacteria

On the basis of nutrition, two types of bacteria are there:

(A) **Heterotrophic bacteria:**

(i) **Parasitic,** *e.g.,* different disease causing bacteria.

(ii) **Saprophytic,** *e.g.,* fermentation bacteria, petrification bacteria.

(iii) **Symbiotic,** *e.g., Rhizobium.*

(B) **Autotrophic bacteria:**

(i) **Photosynthetic,** *e.g., Chromatium, Rhodospirillum.*

(ii) **Chemosynthetic,** *e.g.,* Iron bacteria, sulphur bacteria, nitrifying bacteria, etc.

(For details of bacterial photosynthesis and chemosynthesis, see chapter **'Photosynthesis'** in plant physiology.)

Reproduction in bacteria

Three methods of reproduction are there:

(1) Vegetative reproduction

(2) Asexual reproduction

(3) Sexual reproduction

(1) Vegetative reproduction

(a) **Budding:** It is a rare method of reproduction and is reported in *Bigidi bacterium-bifidus.*

(b) **Binary fission:** It is the most common type of reproduction in bacteria during favourable conditions. Here bacterial cell divides by a constriction into two halves. At the same time nuclear material elongates and divides into 2 equal halves probably helped by mesosomes.

○ Under favourable conditions of binary fission, bacterial cell divides into two after every 20 minutes and at this rate in 24 hours period, a single bacterial cell produces 4 × 10^{21} bacteria, but only about 10% of them survive.

○ Bacteria show **four major phases** of growth in a fresh nutrient rich medium: (1) Lag phase, (2) Log phase (logarithmic or exponential phase), (3) Stationary phase, and (4) Decline phase (death phase). These phases constitute the **standard bacterial growth curve.**

(2) Asexual reproduction

(a) **Endospore formation:** During unfavourable condition, highly resistant single spore is formed inside the bacterial cell, which is known as **endospore. (Endo means inside or within + spore)**

Endospore means spore inside bacterial cell or cell inside cell.

- Endospore formation is more common in rod-shaped bacteria or bacillus forms. Position of single endospore may be terminal or sub-terminal or intercalary.
- Endospore is having a characteristic structure, *i.e.,* having outer thin **exosporium** followed by one or many layered **spore coat,** followed by many concentric layers of **cortex,** which is followed by **cell wall, cell membrane and matrix.**
- Endospore is highly resistant to very high and very low temperature, strong chemicals and acids, etc., due to calcium, dipicolinic acid and peptidoglycan in cortex. Dipicolinic acid (DPA) helps in stabilizing its proteins. DPA and Ca ions provide resistance to heat.
- When favourable conditions come, outer layers rupture and active bacterial cell comes out. So this is a method of perennation (*i.e.,* to tide over unfavourable condition) and some people say it **"reproduction without multiplication".** (The bacterial spore or endospore is perhaps the most resistant living structure known to science.)

(b) **Conidia formation:** Rarely in some filamentous forms of bacteria (*Streptomyces*), conidia are formed.

(c) **Zoospores:** Motile spores are formed in *Rhizobium* bacteria, but are rare in other bacteria.

(3) Sexual reproduction

True sexual reproduction is absent in bacteria, but there occurs **genetic recombination,** *i.e.*, bringing together of genetic material of two bacterial cells. There are 3 main methods of genetic recombination:

(1) Transformation
(2) Transduction
(3) Conjugation

Q. P. 2nd

(1) **Transformation:** Here genetic material of one bacterial cell goes into another bacterial cell by some unknown mechanism and it converts one type of bacterium into another type (Non-capsulated to capsulated form).

This was first studied by **Griffith** (1928) in *Diplococcus pneumoniae* and hence is known as **Griffith effect.** Later on it was studied in detail by **Avery, McCarty** and **McLeod.**

(2) **Transduction:** In this method, genetic material of one bacterial cell goes to other bacterial cell by agency of **bacteriophages** or phages (viruses, infecting bacteria).

- Transduction was first of all reported in *Salmonella typhineurium* by **Zinder** and **Lederberg** (1952).

(3) **Conjugation:** Here cell to cell union occurs between two bacterial cells and genetic material (DNA) of one bacterial cell goes to another cell lengthwise through conjugation tube which is formed by sex pilli.

- Conjugation was first reported by **Lederberg** and **Tatum** (1946) in *E. coli* bacteria.
- Conjugation occurs between Donor cell and Recipient cell. Donor cell is having **sex pilli** and **F-factor** whereas recipient cell is lacking both.
- In donor cell, **F-factor** may unite with main genome or nuclear DNA and this donor cell is called **Hfr-donor cell** (High Frequency donor cell) and here transfer of DNA is rapid.

Importance of bacteria

Bacteria are our 'friends and foes' as they have both useful and harmful activities.

(A) Useful activities

(1) **Role of bacteria in agriculture in increasing soil fertility:** Some free living nitrogen fixing bacteria like *Azotobacter* and *Clostridium* have the capacity of fixing atmospheric nitrogen into nitrogenous substances, hence increase soil fertility.

- Similarly symbiotic bacteria *Rhizobium* also fix atmospheric nitrogen.
- *Nitrosomonas* converts ammonia into nitrites, which is further converted into nitrates by *Nitrobacter* (nitrification).

(2) **Dairy industry:** Lactic acid bacteria (*Bacterium lactici-acidi* and *Bacterium acidi-lactici*) convert lactose of milk into lactic acid and hence milk turns sour.

Pasteurization: Milk is heated at 62.8°C for 30 min or 71.7°C for 15 sec only. This reduces the number of bacteria by killing all non-spore forming bacteria and thus unboiled milk becomes sour earlier than boiled milk.

- Lactic acid bacteria unite casein protein of milk in the form of small droplets and thus form **curd** and hence **butter.**

(3) **Role of bacteria in other industries:** In **vinegar industry,** *Acetobacter aceti* converts sugar solution into **acetic acid.**

- **Butyl alcohol** and **acetone** are produced by activity of *Clostridium acetobutyricum.*

Retting of fibres: Retting or separation of fibres from stalks, *e.g.*, in jute, sunn hemp, *Linum* (flax), etc., is done by water inhabiting bacteria *Clostridium butyricum.*

- Flavouring of tobacco leaves is done by *Bacillus megatherium.*
- Curing of leaves of tea is done by *Mycococcus condisans.*

(4) **Role of bacteria in medicines:** Many **antibiotics** are produced from bacteria.

- **Waksman** was the first person who gave the term antibiotics to the chemical substances which are produced by one micro-organism and which kill other micro-organisms or chemical substances of **microbial origin** and having **antimicrobial activity.**
- These are also known as **magic bullets.** The first antibiotic produced was **penicillin** (wonder drug) obtained from fungus *Penicillium notatum* by **Sir Alexander Fleming (1923),** which checks growth of Gram +ve bacteria by inhibiting cell wall synthesis or by blocking peptidoglycan synthesis.
- The first antibiotic produced from **bacteria** by **Waksman** was **thiothricin** from *Bacillus brewis.*

Other important antibiotics of bacterial origin are:

Antibiotics	Bacteria from which obtained
(1) Subtelin	*Bacillus subtilis*
(2) Polymyxin	*Bacillus polymyxa*
(3) Streptomycin and Cycloheximide	*Streptomyces griseus*
(4) Chloromycetin (Chloramphenicol)	*Streptomyces venezuelae*
(5) Terramycin (Oxytetracycline)	*S. rimosus*
(6) Aureomycin (Chlorotetracycline)	*S. aureofaciens*
(7) Erythromycin	*S. erythraeus*
(8) Neomycin	*S. fradiae*

- Streptomycin, chloromycetin and erythromycin check bacterial growth by inhibiting their protein synthesis. Polymyxin on the other hand destroys cell membrane.

(5) **Role of bacteria in sewage disposal:** Sewage is household or industrial water borne wastes. For the breakdown of

sewage into simple substances, bacteria and algae play important role.

- Sewage oxidation ponds or tanks have luxuriant growth of bacteria and algae.

(6) **Role of bacteria in petroleum pollution:** Petroleum pollution in water bodies is checked upto some extent by *Pseudomonas*.

- Genetically engineered strain of *Pseudomonas putida* (Superbug) was developed by Dr. Ananda Mohan Chakraborty (USA) which biodegrade spilled oil. These superbugs were allowed by USA government in 1990 for removal of oil from water.

(7) **Role of bacteria in human being:** *E. coli* (gram –ve) bacteria live in colon region of intestine of man and other animals and play an important role in digestion process.

(B) Harmful activities

1. Diseases:

- Most of the pathogenic bacteria are **Gram –ve, rod-shaped** (Bacillus) and **non-spore forming.** (Bacteria causing **anthrax** and **tetanus** are endospore forming or spore forming).

Name of Disease	Bacteria
(a) In human beings	
Pneumonia	— *Diplococcus pneumoniae*
Typhoid	— *Salmonella typhosa*
Cholera	— *Vibrio cholerae*
Plague	— *Pasteurella pestis*
Meningitis	— *Neisseria meningitides*
Gonorrhoea	— *Neisseria gonorrhoeae*
Syphillis	— *Treponema pallidum*
Diorrhoea	— *Bacillus coli*
Gastroenteritis	— *E. coli*
Diptheria	— *Corynebacterium diptheriae*
Tuberculosis	— *Mycobacterium tuberculosis*
Gangarin	— *Clostridium perfringens*
Jaundice	— *Leptospira icterohaemorrhagae*
Whooping cough	— *Haemophilus pertussis* or *Bordetella pertussis*
Tetanus (lockjaw)	— *Clostridium tetani*
Bacterial dysentry	— *Shiegella dysentriae*
Leprosy	— *Mycobacterium leprae*
(b) In animals	
Anthrax	— *Bacillus anthracis*
Black leg disease	— *Clostridium chauvi*
(c) In plants	
Soft rot of potato	— *Pseudomonas solanacearum*
Citrus Canker	— *Xanthomonas citri*
Bacterial blight of paddy	— *Xanthomonas oryzae*
Tundu disease in wheat	— *Corynebacterium tritici*
Potato wilt	— *Pseudomonas solanacearum*
Fire blight of apple and peach	— *Erwinia amylovora*
Crown gall of sugar beet	— *Agrobacterium tumefaciens;*
Black rot of cabbage	— *Xanthomonas campestris*

2. Cotton spoilage: It is done by bacteria called *Spirochaete cytophage*.

3. Food-poisoning (botulism): It is done by a bacteria called *Clostridium botulinum.*

It is a gram +ve, rod shaped bacterium which affects **neuromuscular junction.**

- Food-products are generally stored after drying or adding sugars or salts so that bacterial cells are plasmolysed and killed.

4. Reduction of soil fertility: There are some denitrifying bacteria in soil, which convert **nitrates into free nitrogen** (denitrification), *e.g., Bacillus denitrificans, Micrococcus denitrificans* and *Thiobacillus denitrificans.*

Important points to remember

Pasteurization: Kills all non-endospore forming bacteria.

Sterilization: Kills all living micro-organisms. It occurs at 100°C temperature and 15 pounds pressure followed by 120°C to 126°C temperature for 12 to 19 minutes.

Lyophilization: Low temperature storage of bacteria is called Lyophilization.

Some characteristic features of *Escherichia coli (E. coli)* bacteria

This bacterium was discovered by a German scientist Escherisch from **colon region of intestine**, hence called *Escherichia coli* (*E. coli*).

- It is **bacillus** (rod-shaped) form of bacteria and is reported in colon region of intestine of warm blooded animals including human beings. It is 1–3 μ in length and 0.4–0.7 μ in diameter.
- It is **gram –ve bacterium.** Slime layer or capsule is present in some strains of *E. coli.*
- *E. coli* is **a peritrichous** bacterium, *i.e.*, flagella are present all over the surface of bacterium. Further, **pilli** are also present on surface, including sex-pilli, which form conjugation tube during conjugation.
- It is a **facultative anaerobic** bacterium and optimum temperature for it is about 37°C, although it lives between 10–40°C.
- There are 1–4 circular DNA molecules in *E. coli.* There are about 3000 genes in *E. coli.* DNA in *E. coli* is double stranded, circular with estimated length of 1000 μ.

- Chemically *E. coli.* has about 70% H_2O, 15% proteins, 6% RNA, 1% DNA, 2% lipids, 3% carbohydrates, etc.
- Conjugation as a method of genetic recombination (sexual rep.) occurs in *E. coli*, which was reported by Lederberg and Tatum (1946).
- *E. coli* is important research material due to its short life cycle, haploid nature and genetic recombinations. The mechanism of gene action and protein synthesis has been studied in it. Besides regulation of protein synthesis (Operon model) has been studied in *E. coli* by Jacob and Monod (1961).

Spirochaetes

These are free inhabitants of mud and water and are **chemoheterotrophic** bacteria. These are spiral or helicoid in shape, covered by flexible cell wall and swim actively with flagella present at both poles or ends. Many diseases are caused by them as *Treponema pallidum* causes syphilis, *Leptospira* causes infectious jaundice and *Borrelia* causes relapsing fever. Besides some spirochaetes are found in teeth.

Actinomycetes

Actinomycetes

These are filamentous bacteria (like moulds or fungi). These are generally present as decomposers in soil. They reproduce asexually by means of **conidia** produced at tips of filaments. Most of these secrete chemical substances having antimicrobial activities, called **antibiotics**, *e.g.*, *Streptomyces* species secrete streptomycin, neomycin, chloromycetin, terramycin, erythromycin, etc.

Archaebacteria

This is simplest and most primitive group of bacteria. The cell wall of these bacteria is made of polysaccharides and proteins (peptidoglycans and muramic acid are absent in cell wall). Further **branched chain lipids** are present in plasma membrane of archaebacteria, due to which these can face extremes of conditions of temperature and pH. Three main groups of archaebacteria are:

(i) **Methanogens:** These are strict anaerobic bacteria and mainly occur in **muddy areas** and also in **stomach of cattle**, where cellulose is fermented by microbes. These are responsible for methane gas (CH_4) formation in bio-gas plants, because they have capacity to produce CH_4 from CO_2 or formic acid (HCOOH).

(ii) **Salt lovers archaebacteria or halophiles:** These are also **anaerobic** bacteria, which occur in **extreme saline** or salty conditions (upto 35% of salt or NaCl in culture medium). A purple pigmented membrane containing **bacteriorhodopsin** is developed in sunlight in these bacteria, which utilizes light energy for metabolic activities (different from photosynthesis).

(iii) **Thermoacidophiles:** These are the bacteria which are found in **hot sulphur springs** (upto 80°C). As against first two groups of archaebacteria, these are **aerobic bacteria**. These have the capacity to oxidize sulphur to H_2SO_4 at high temperature and high acidity (*i.e.*, pH 2.0), hence given the name **thermoacidophiles**, *i.e.*, temperature and acid loving. Some of these bacteria are able to reduce sulphur to H_2S under anaerobic conditions.

- Archaebacteria are considered to be **'oldest of living fossils'**.

Cyanobacteria

e.g. Nostoc.

The new name cyanobacteria has been given to **blue-green algae** or **myxophyceae** or **cyanophyceae** class of algae due to their simple prokaryotic organization like bacteria.

According to 5-kingdom classification of **Whittaker**, true bacteria (Eubacteria), Archaebacteria and Cyanobacteria have been included in kingdom **Monera**.

Two groups of **oxygenic photosynthetic bacteria** are there—Cyanobacteria and order-Prochorales (with two genera, *Prochloron* and *Prochlorothrix*).

- The *cyanobacteria* are the largest and most diverse group of photosynthetic bacteria. There are as many as 2,000 or more cyanobacterial species.
- G + C content of this group ranges from 35 to 71%.
- Although cyanobacteria are **true prokaryotes**, but their photosynthetic system closely resembles with that of eukaryotes because they have **chlorophyll a** and **photosystem II** and they carry out **oxygenic photosynthesis**. Like the red-algae, cyanobacteria use phycobiliproteins as accessory pigments. Photosynthetic pigments and electron transport chain components are located in thylakoid membranes lined with particles called **phycobilisomes**, which contain phycobilin pigments, particularly **phycocyanin** and transfer energy to photosystem II.
- CO_2 is fixed through C-3 cycle or **Calvin cycle** and the reserve carbohydrate is **glycogen**. Sometimes they store extra nitrogen as polymers of arginine or aspartic acid in cyanophycin granules.
- Cyanobacteria do not have a fully functional Krebs' cycle or citric acid cycle as they lack enzyme α-ketoglutarate dehydrogenase. Pentose phosphate pathway (PPP) plays a central role in their carbohydrate metabolism.
- Most of the cyanobacteria are **obligate photolithoautotrophs** but some can grow slowly in dark as chemoheterotrophs by oxidizing glucose and other sugars. They show considerable metabolic flexibility.
- Cyanobacteria vary greatly in their shape and appearance. They range about 1–10 μ in diameter and may be unicellular, exist as colonies of many shapes, or form filaments called **trichomes**.
- Cyanobacteria have typical prokaryotic cell structures and a normal **gram-negative type** cell wall.
- They often use **gas vesicles** to move vertically in water and many filamentous species have **gliding motility**.
- Cyanobacteria **lack flagella** but marine genus *Synechococcus* are able to move at the rate of 25 μ/second by some unknown mechanism.
- Cyanobacteria reproduce by binary fission, budding, fragmentation and multiple fission. Fragmentation of filamentous cyanobacteria can generate small, motile filaments called **hormogonia**. Some species develop **akinetes**.
- Many filamentous or trichome-forming cyanobacteria fix

atmospheric nitrogen by means of special thick-walled cells called heterocysts. About 5–10% cells of a trichome develop into heterocysts, which obtain nutrients from adjacent vegetative cells and contribute fixed nitrogen in the form of amino acid glutamine.

- There are **five orders** of cyanobacteria—**Chroococcales** (*Chamaesiphon, Gleocapsa, Synechococcus*); **Pleurocapsales** (*Pleurocapsa, Dermocarpa*); **Oscillatoriales** (*Lyngbya, Spirulina, Oscillatoria*); **Nostocales** (*Anabaena, Nostoc, Cylindrospermum, Scytonema*); **Stigonematales** (*Stigonema, Fischerella*).
- Cyanobacteria are highly tolerant of environmental extremes and are present in almost all aquatic and terrestrial environments. Thermophilic species may grow at temperatures upto 75°C in alkaline hot springs. Some unicellular forms grow in fissures of desert rocks. In eutrophic warm ponds and lakes, **surface cyanobacteria** like *Anabaena* and *Anacystis* can reproduce rapidly to form blooms. The death of bloom micro-organisms releases organic matter, which stimulates the growth of chemoheterotrophic bacteria which deplete the available oxygen and this kills fish and other organisms.
- *Oscillatoria*, a cyanobacterium is highly pollution resistant and grows in fresh water with high organic matter, acts as **indicator of water pollution.**
- Cyanobacteria successfully develop symbiotic relations with other organisms. These are photosynthetic partners in many lichens. Further, these are symbionts with protozoa, liverworts, mosses, gymnosperms and angiosperms.

o The cyanobacterium *Spirulina* is cultivated for human consumption and has a dry weight protein content of about 70%. This is common in saline lakes and is sold as a nutritional food supplement in most health food stores in USA.

MYCOPLASMA

In 18th century in Europe a disease called **Bovine pleuropneumonia** spread in cattle, which caused **havoc** in cattle. Initially it was thought to be caused by a virus but later on it was found to be caused by some different micro-organism.

- Pasteur (1843) first discovered them from pleural fluid of cattle, suffering from pleuropneumonia, which were called PPLO (Pleuro pneumonia like organisms), but he couldn't obtain them in pure culture.
- **Nocard** and **Roux (1898) first obtained their pure culture.**
- **Borrel** *et al.* (1910) gave them the name *Asterococcus.*
- **Nowak** (1929) gave them the name *Mycoplasma.*
- Mycoplasma are the **smallest known aerobic prokaryotes** without cell wall. The smallest cell so far discovered is of *Mycoplasma gallisepticum* having a diameter of 0·1 μ.
- Mycoplasma have been reported to cause a number of plants and animal diseases and these have also been reported from urinogenital tract of human beings.
- Three characteristic features of mycoplasma are:

aerobic

1. **They are lacking cell wall.**
2. Typical colonial appearance.
3. Filterability through 450 nm bacterial filters.

o As mycoplasma have no cell wall, hence have no definite shape, *i.e.*, **pleomorphic** and thus are called **Jokers of microbiology.**

Culture of mycoplasma

These can be cultured in non-living medium, although they grow well in living medium containing chick tissue.

In non-living medium, they require agar-agar (obtained from red algae), blood serum and pH 7·8.

Structure of mycoplasma

The structure of Mycoplasma varies from species to species, *e.g.*, in *Mycoplasma mycoides,* filamentous form and in *Mycoplasma pneumoniae,* coccus (rounded) form occurs. On outer side, there is tripartite (3-layered) cell membrane, made of **lipoproteins** as usual.

In stationary phase, mesosomes are also present on plasma membrane or cell membrane. Inner to cell membrane, matrix is present, which is mainly having double stranded, long, circular DNA, single stranded RNA (in both ribosomes and cytoplasm), ribosomes of 70-S type and many metabolites like proteins (enzymes) and fatty substances. There is 4% DNA and 8% RNA.

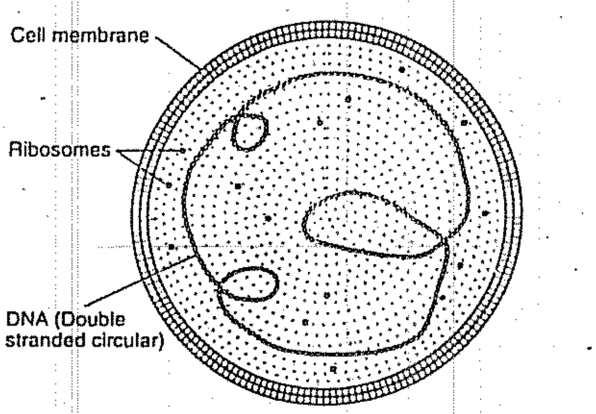


Fig. 9.4. Structure of a typical mycoplasma cell

Difference between L-form bacteria and Mycoplasma

In the culture of bacteria, some bacterial cells are developed which are without cell wall and such **bacterial cells which are without cell walls are known as L-form bacteria ('L' for Lister institute, where these were reported).**

o Important difference between L-form bacteria and mycoplasma is that under optimum nutritional conditions, L-form bacteria **will develop cell walls whereas mycoplasma will never develop cell wall.**

Reproduction in mycoplasma

1. **Budding.**
2. **Fragmentation:** Specially in filamentous forms.

3. **Binary fission:** Most common method of reproduction in mycoplasma is binary fission.

Bleb and infra bleb are peculiar structures which are formed at both ends during binary fission in mycoplasma and as soon as binary fission is complete, these structures disappear, so the significance of bleb and infra bleb is not known.

Evolutionary significance

On the basis of evolution they are present between viruses and bacteria, *i.e.*, Viruses → Mycoplasma → Bacteria.

Diseases caused by mycoplasma

- In human beings, *Mycoplasma hominis* causes pleuropneumonia, infertility in man and inflammation in genitals. *Mycoplasma pneumoniae* causes Primary Atypical Pneumonia (PAP). Besides arthritis, respiratory infections and rheumatism are also caused by mycoplasma.
- In plants, important diseases of mycoplasma are:
  1. London sewage disease in brinjal and tomato.
  2. Little leaf of brinjal.
  3. Large big bud in tomato.
  4. Clover dwarf.
  5. Bunchy top of papaya.
  6. Maize stunt.
  7. Mulberry dwarf.
  8. Aster yellows.
  9. Potato witche's broom, etc.

viscous fluid.

o Mycoplasma are insensitive to penicillin and can be killed by using chloramphinicol, streptomycin and erythromycin.

venom

VIRUSES

The term 'virus' has been derived from Latin, which means **poison or venom or viscous fluid.**

- Viruses were discovered after **Chamberland** developed bacterial filters (1884).
- **Meyer** (1886) described tobacco mosaic disease but he couldn't isolate the causal organism. Further, he said that the disease is transmissible and infectious.
- Actual credit for the discovery of viruses goes to the Russian botanist **D. Ivanowski** (1892), when he discovered the causal organism of tobacco mosaic disease and this causal organism could pass through the filters which retained bacteria.
- **Beijerinck** (1898) confirmed the earlier studies and named these organisms as **"contagium vivum fluidum"**, *i.e.*, living infectious fluid.
- **F.W.T' wort** (1915) and **F.H. d'Herelle** (1917) discovered certain viruses which infect bacteria or **bacteria eaters**, *i.e.*, **bacteriophages or phages.**
- **Stanley** (1935) crystallized tobacco mosaic virus and said that these crystals retain their infectivity for a long time if kept in bottles.
- **Bawden and Pirie** (1937) first of all studied the chemical nature of viruses and said that these are **nucleoproteins.**

Bawden and Pirie defined viruses as, **"Submicroscopic organisms** which are generally less than 200 mμ in size, are obligate parasites and can pass through bacterial filters."

Nowadays, these are defined as, **"Viruses are infectious nucleoproteins."**

Characteristic features of viruses

1. These are submicroscopic organisms generally less than 200 mμ.
2. They are obligate parasites, *i.e.*, can live inside living host only.
3. They have either RNA or DNA.
4. They can pass through bacterial filters.
5. They have characteristic mode of multiplication, *i.e.*, once a virus enters into the host cell, it takes control of whole biochemical machinery of host cell and orders the metabolic machinery to synthesize their own (viral) components.

Non-living characters of viruses: Imp.

1. No protoplasm.
2. No enzyme system.
3. No respiration.
4. They can be crystallized.
5. Do not grow in culture medium.

Living characters of viruses: Imp.

1. They contain nucleic acid as a result of which they are capable of synthesizing proteins.
2. They can multiply inside living host cell.
3. They cause diseases.

On the basis of above characters it can be said that viruses form a transitional group between living and non-living.

Classification of viruses

F. O. Holmes (1948) divided order-virales into three sub-orders.

1. **Phytophaginae:** Viruses, infecting plants.
2. **Zoophaginae:** Viruses, infecting animals.
3. **Phaginae:** Viruses, infecting bacteria.

Nomenclature of viruses

Gibbs and Harrison (1968) gave a system of naming viruses. According to this system, each virus is given a name made of 4 pairs, which is known as **cryptogram**, *e.g.*, cryptogram of Tobacco Mosaic Virus (TMV) is: R/1 : 2/5 : E/E : S/*

1st pair: Type of nucleic acid/number of strands in nucleic acid.

2nd pair: Molecular weight of nucleic acid in million/ percentage of nucleic acid in virus.

3rd pair: Shape of virus/shape of capsid.

4th pair: Type of host infected/type of vector.

Morphology and structure of viruses

Size

Less than 200 mμ.

- **Smallest virus is foot and mouth disease virus** (10 mμ).
- **Largest virus is smallpox virus** or virus-*Variola* (250 mμ).

Shape

Variable, *e.g.*, **Brick shaped** → Smallpox virus.

Spherical → Influenza virus.

Rod shaped → TMV.
Tadpole-like → Bacteriophages.

Chemical composition

Chemically there are two components of viruses:
(1) Nucleic acid core
(2) Protein coat.

1. **Nucleic acid:** Either RNA or DNA.

- Generally in plant viruses, RNA is present but in cauliflower mosaic virus, DNA is present.
- Generally in animal viruses, DNA is present but in following animal viruses, RNA is present:
    (i) Influenza virus: Single stranded RNA.
    (ii) Rous sarcoma virus: Single stranded RNA.
    (iii) AIDS virus: Single stranded RNA.
- Single stranded RNA viruses (*e.g.*, AIDS virus) which carry few molecules of **reverse transcriptase** enzyme (which copies RNA into DNA, *i.e.*, reverse transcription), are called **retroviruses**.
    (iv) Poliomyelitis virus: Single stranded RNA.
    (v) Reovirus: Double stranded RNA.
- In bacteriophages, generally DNA is present but in MS_2, F_2, r-17 **bacteriophages**, RNA is present.
- Generally DNA is double stranded but in $\phi \times 174$ bacteriophage and S/3. *E. coli* phage, DNA is single stranded.
- Generally RNA is single stranded but in Reoviruses, Wound tumour viruses and Rice dwarf virus, RNA is double stranded.
- (Total number of genes is about a hundred for a large virus, *e.g.*, *Vaccinia* (cowpox virus) or 3 or 4 for the smallest virus).

2. **Protein coat:** It is known as capsid and it is made of structural units called capsomeres. Number, size and structure of capsomeres vary and these capsomeres are arranged in different manners to form different types of symmetry.

- (As in a virus particle, protein shell or coat (capsid) surrounds the genome (nucleic acid) and thus is called **nucleocapsid**).
- In some mammalian viruses, outside the capsid there is another membrane which is known as **limiting membrane or mantle.**

Symmetry of viruses

1. **Helical symmetry:** Capsomeres are arranged in helical manner in the capsid, *e.g.*, TMV and influenza virus.
2. **Cubical symmetry:** Capsomeres are arranged on the surface to form a 20 sided cube, *e.g.*, Turnip Mosaic Virus.
3. **Bisymmetrical or Mixed symmetry:** *e.g.*, Bacteriophages.

TMV (Tobacco Mosaic Virus)

- It is the most thoroughly studied virus and was discovered by the Russian worker **D. Ivanowski** (1892).
- It is rod shaped virus measuring 300 × 18 nm.
- It is having **helical** symmetry.
- Having single stranded RNA which is 330 nm in length and having 7300 **nucleotides**.

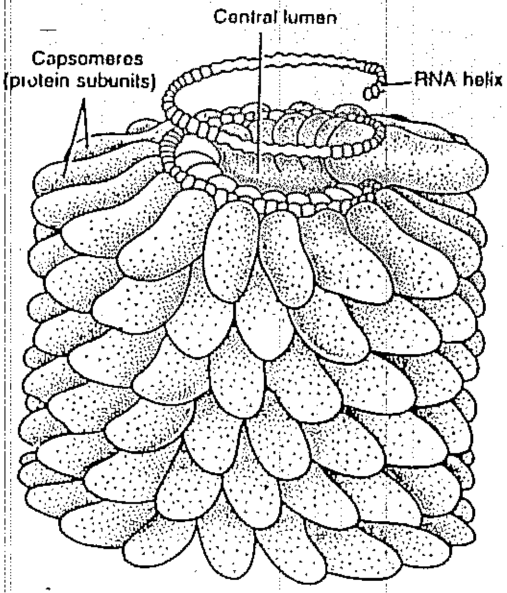


Fig. 9.5. Structure of Tobacco Mosaic Virus

- Number of capsomeres in capsid is **2130.**
- 5% RNA and 95% protein is present in TMV.

Influenza virus

Spherical virus, infecting respiratory tract.

- Having helical symmetry. 10% RNA and 90% protein is present in influenza virus.
- Having single stranded RNA, killed at 65°C and active at low temperature.
- Cryptogram of influenza virus: R/1 : 2-3/10 : S/E : V/A

Bacteriophages

F.W. T'wort (1915) and d'Herelle (1917) discovered certain viruses which infect bacteria and these are known as **bacteriophages or phages.** Seawater can hold 100 **million** bacteriophages per mL.

- Coliphage is the virus infecting *E. coli* bacteria (discovered by d' Herelle).
- Cyanophages are viruses infecting blue-green algae or cyanophyceae or cyanobacteria. (The first cyanophage or algal virus was discovered and isolated from 3 blue-green algal genera: *Lyngbya, Phormedium* and *Plectonema*, hence called **LPP-1**).

Safferman and Morris (1963) discovered cyanophages and these are having double stranded DNA.

Types of bacteriophages

Broadly of 2 types:

1. **Prophages or non-virulent phages or non-infective phages:** The phages which don't cause lysis of bacteria soon after their formation inside, are called prophages. Such bacterial cells which are having prophages inside them are called Lysogenic bacteria.

2. **Virulent phages or infective phages:** The phages which cause lysis of bacterial cell at once are called virulent phages.
   - Most studied series of bacteriophages is T-series, *i.e.*, T_2, T_4, T_6, etc. (T-even phages are characterized by angular head and contractile tail).

Structure of bacteriophages

Having tadpole-like structure, *i.e.*, with head and tail and inside the head is present nucleic acid, generally DNA. Head is prism-like **hexagonal** having length 950 Å and breadth 650 Å. Tail is also 950 Å in length, joined to head by neck and collar. Tail is having hollow core of 80 Å and is surrounded by tail sheath. At the end of tail, end plate is present to which 6 tail fibres are attached, each is 1500 Å in length.

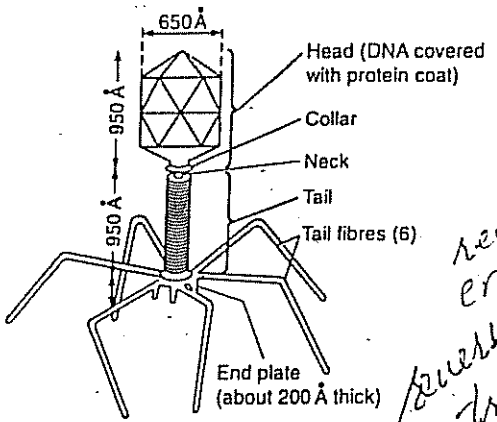

650 Å
950 Å
950 Å
Head (DNA covered with protein coat)
Collar
Neck
Tail
Tail fibres (6)
End plate (about 200 Å thick)

Fig. 9.6. Structure of bacteriophage

reverse enzyme
Reverse and
more
transcription
enzyme

Multiplication

The main steps are:

1. **Adsorption:** Bacteriophage is attached to bacterial cell surface with the help of tail fibres.
2. **Penetration:** Only DNA of phage or N. Acid enters into the bacterial cell through a pore formed by lysozyme secreted by tail fibres. Protein coat is left outside, which is known as ghost or doughnut.
3. **Control of metabolic activity of bacterial cell and formation of new phage components, which unite to form 100–300 new phages within 15–20 minutes.**
4. Lysis of bacterial cell to release new phages.

Applications of bacteriophages

1. Used in studying viral infection mechanism.
2. Used in control of certain bacterial diseases (as phages are very specific in relation to their host).
3. Purity of holy Ganges is due to presence of bacteriophages.

Mycophages

Viruses, infecting fungi are called mycophages. Mycophages were first of all discovered by Sinden (1957) in *Agaricus bisporus*. These are having double stranded RNA and are spherical or polygonal in shape.

head tail [illegible]

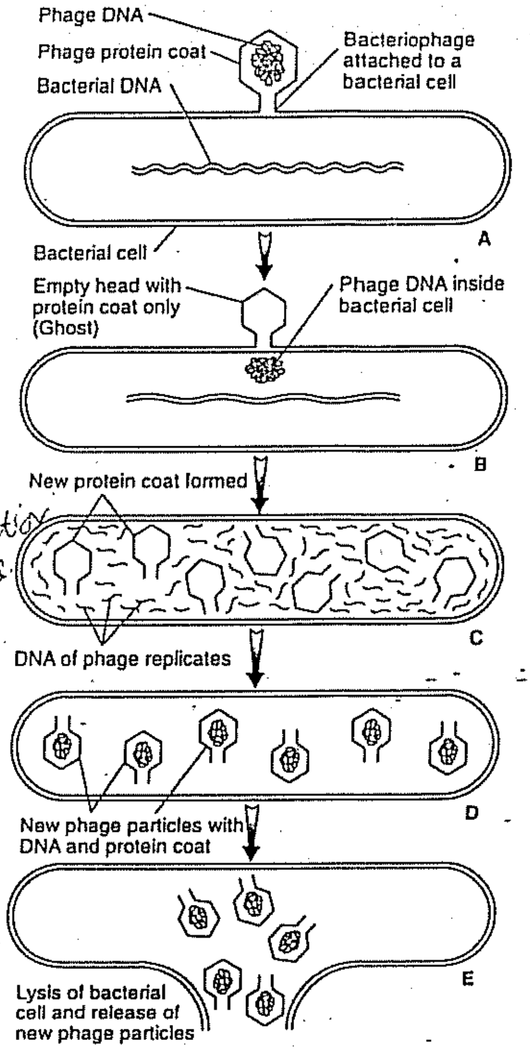

Phage DNA
Phage protein coat
Bacterial DNA
Bacteriophage attached to a bacterial cell
Bacterial cell
A
Empty head with protein coat only (Ghost)
Phage DNA inside bacterial cell
B
New protein coat formed
C
DNA of phage replicates
D
New phage particles with DNA and protein coat
E
Lysis of bacterial cell and release of new phage particles

Fig. 9.7. Multiplication in bacteriophage

Viroids

T.O. Diener (1971) discovered some new infectious agents, which are still smaller than viruses. These **sub-viral infectious agents are called viroids.**

- Viroids contain only very low mol. wt. RNA and not protein coat.
- **Viroids cause Potato spindle tuber disease (PSTV), Chrysanthemum stunt, Citrus exocortis, Cucumber pale fruit,** etc.
- Viroids cause persistent infections, *i.e.*, never recovered.

Prions or Slow viruses

Stanley B. Prusiner discovered certain infectious agents or slow viruses which contain only **proteins.** Prions cause scrapie disease in sheep and goat and **Kuru disease** (disease of nervous system).

- Prusiner got Nobel Prize for this work in 1997.

Virion

Completely assembled virus particle outside host is called **virion.**

Interferons

G.M. Findley and McCallum (1937) reported a phenomenon called **viral interference** in which the cell infected with one type of virus becomes resistant to superinfection by other viruses. **Alliac Issacs** and **Lindeman** (1957) gave the term **interferons** to the chemical substances responsible for viral interference.

- Interferons are produced by cells in mammals, rodents, birds, etc., and provide resistance against viruses.
- **Hilleman** and **A. Tydall** (1963) isolated interferons from hen's egg infected with influenza virus.
- Interferons are **protein molecules or polypeptides of low molecular weight** which prevent viral multiplication.

Diseases caused by viruses

Plant diseases

1. Tobacco mosaic disease.
2. Leaf curl of papaya.
3. Yellow vein mosaic of bhindi.
4. Potato leaf roll.
5. Vein banding mosaic disease of potato.
6. Grassy shoot of sugar cane.
7. Bunchy top of banana.
8. Tungro disease of rice.
9. Tomato leaf curl, etc.

virus

Human diseases

(A) **Pneumotropic diseases** (Related to respiratory tract), *e.g.*, **Influenza, Adenovirus Infection, Rhinovirus infection.**

(B) **Dermotropic diseases** (Related to skin):

1. **Chickenpox—Varicella virus:** This virus also causes **Herpes zoster** disease in adults. Therefore this virus is known as **v-z virus.**
2. **Smallpox—Variola virus** (Largest virus).
3. **Measles:** Highly communicable infection in children, caused by **Rubeola virus** (Rube → Red).
4. **Kawasaki disease.**
5. **Mumps** or epidemic parotitis.
6. **Herpes simplex.**

(C) **Viscerotropic diseases** (Related to blood and organs):

1. **Rabies or Hydrophobia** (Highest mortality rate): This virus is having single stranded RNA.

- The shape or appearance of virus is **bullet shaped.**

2. **AIDS:** (Acquired Immuno Deficiency Syndrome).

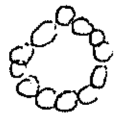
- First case of AIDS was reported in **Atlanta** (1981).
- This is suspected to be a monkey's virus.
- 5–10 million people in the world are infected with this virus and in America alone 80% cases.
- Males are more susceptible to this disease than females. (92·5% in males, 6·5% in women and about 1% in children).
- This virus spreads through blood transfusion, sexual contact, etc.
- This AIDS virus is known by different names as:
  - (a) **ARV:** AIDS associated Retrovirus.
  - (b) **LAV:** Lymphoadenopathy Associated Virus.
  - (c) **HTLV-III:** Human T-cell Lymphotropic Virus Type-III.
  - (d) **HIV:** Human Immunodeficiency Virus.
- This virus contains single stranded RNA.
- AIDS virus likes T-lymphocytes which provide resistance to the organism through production of antibodies.

This virus infects and kills T-lymphocytes (T-helper cells) and hence resistance of host is collapsed. Thus man is infected with different types of infections.
[This is also known as **Death Warrant.**]

3. **Yellow fever:** Transmitted by *Aedes aegypti* mosquito.
4. **Dengue fever:** Transmitted by *Aedes aegypti* and *Culex fatigans* mosquito.
5. **Polio:** Transmitted through food, water and contact.
6. **Hepatitis A:** Transmitted through food, water and contact.
7. **Hepatitis B:** Transmitted through contact and body fluids.

MULTIPLE CHOICE QUESTIONS

1. Bacteria were discovered by: (BHU 1993; AFMC 1997)
   (a) Linnaeus (b) Pasteur
   (c) Robert Koch (d) Leeuwenhoek
2. The term bacterium was given by:
   (a) Pasteur (b) Lister
   (c) Leeuwenhoek (d) Ehrenberg
3. The bacteria were first of all cultured by:
   (a) Lister (b) Louis Pasteur
   (c) Robert Koch (d) None of these
4. Who put forward 'Germ theory of disease'?
   (a) Ivanowski (b) Stanley
   (c) Koch (d) Pasteur
5. Mitosis is present in which bacterium?
   (a) *Clostridium botulinum* (b) *Bacillus megatherium*
   (c) *Nitrosomonas* (d) None of these
6. Which organelle is called 'Chondrioide' in bacteria?
   (a) Mitochondria (b) Chromatophores
   (c) Pilli (d) Mesosomes.
7. The function of Mesosome is:
   (a) Respiration
   (b) Equal distribution of genetic material
   (c) Both (a) and (b)
   (d) None of the above
8. Which is present in cell wall of bacteria?
   (a) N. phenyl glucosamine (b) N-acetyl phenyl amine
   (c) N. acetyl glucosamine (d) None of these
9. Largest known bacterium is:
   (a) *Spirillum volutans*
   (b) *Bacillus buschili* in man
   (c) *Bacillus buschili* in cockroach
   (d) *Epulopiscium fishelsoni*
10. Outermost layers of cell wall of Gram +ve and Gram –ve bacteria are of:
    (a) Glycoproteins and Lipoproteins respectively
    (b) Lipoproteins and Muramic acid respectively
    (c) Lipoproteins and Teichoic acid respectively
    (d) Teichoic acid and Lipopolysaccharides respectively
11. *E. coli* is a bacterium:
    (a) Monotrichous (b) Lophotrichous
    (c) Amphitrichous (d) Peritrichous
12. When a group of flagella is present at one end only, bacteria is called:
    (a) Amphitrichous (b) Lophotrichous
    (c) Peritrichous (d) None of these
13. When cubical packets of 8 or 64 or more cocci bacteria are present, these are called:
    (a) Streptobacillus (b) Staphylococcus
    (c) Sarcina (d) Streptococcus
14. Presence or absence of capsule in bacteria is due to:
    (a) Nutrition provided (b) Environmental factors
    (c) Genetically fixed (d) None of these
15. Slime layer is made of:
    (a) Lipids and proteins
    (b) Polysaccharides and lipids
    (c) Polysaccharides and amino acids
    (d) None of these
16. Which of the bacteria are immunologically virulent?
    (a) R-type (b) S-type
    (c) Both R and S-Type (d) None of these
17. In the cell wall of Gram –ve bacteria:
    (a) Both horizontal and vertical peptide linkages are present
    (b) Only horizontal
    (c) Only vertical
    (d) Either horizontal or vertical peptide linkages
18. Cell wall of bacteria contains: (CPMT 2003)
    (a) N-acetyl glucosamine (b) Muramic acid
    (c) Diaminopimelic acid (d) All of these
19. Which is correct for plasma membrane of bacteria?
    (a) Made of polysaccharides and proteins
    (b) Sterols are absent
    (c) Impermeable
    (d) None of the above
20. Which is correct for flagellum of bacteria?
    (a) Made of flagellin protein
    (b) 9 + 2 pattern absent
    (c) 4 – 5 µ long
    (d) All of the above



21. 'Pilli' are essentially present in:
    (a) Gram +ve bacteria
    (b) Gram –ve bacteria
    (c) Both Gram +ve and Gram –ve bacteria
    (d) None of the above
22. Function of pilli is:
    (a) Attachment to other organisms
    (b) Form conjugation tube
    (c) Both (a) and (b)
    (d) None of the above
23. Which is not correct for DNA of bacteria?
    (a) Double stranded
    (b) Right handed and circular
    (c) G-C contents more than A-T contents
    (d) Histones absent
24. The term 'plasmid' was given by:
    (a) Beadle (b) Koch
    (c) Lederberg (d) Zinder

*25. F-factor in bacteria is:
    (a) Plasmid (b) Episome
    (c) Colicin factor (d) None of these

26. Volutin granules in bacteria are chemically:
    (a) Butyric acid granules
    (b) Fatty acid granules
    (c) Protein granules
    (d) Polymetaphosphate granules
27. Binary fission in bacteria occurs after every:
    (a) 1 hr (b) 2 hrs
    (c) 20 minutes (d) 2 minutes
28. Endospore formation generally occurs in:
    (a) Coccus form (b) Vibrio form
    (c) Bacillus form (d) Spirillum

29. Highly resistant spores in bacteria are:
(a) Chlamydospore (b) Hypnospore
(c) Endospore (d) Akinetes

30. Which of the following is characteristic of endospore?
(a) Ca^{2+} (b) Peptidoglycan
(c) Dipicolinic acid (d) All of these

31. Which method in bacteria constitutes 'Reproduction without multiplication'?
(a) Conidia (b) Binary fission
(c) Endospores (d) Zoospores

32. Which of the following method of genetic recombination is called 'Griffith effect'?
(a) Transduction (b) Transformation
(c) Conjugation (d) None of these

33. 'Transduction' method of genetic recombination was first of all reported in: **(EAMCET 2002)**
(a) *Diplococcus pneumoniae*
(b) *Salmonella typhineurium*
(c) *E. coli*
(d) *Rhizobium*

34. Pasteurization of milk occurs at: **(MPPMT 2002)**
(a) 61.8°C for 20 min (b) 62.8°C for 30 min
(c) 62.8°C for 1 hr (d) None of these

35. Which is free living N_2 fixing bacteria?
(a) *Rhizobium* (b) *Streptomyces*
(c) *Nitrobacter* (d) *Azotobacter*

36. 'Fibre retting' is done by:
(a) *Clostridium acetobutylicum*
(b) *Micrococcus condisans*
(c) *Clostridium botulinum*
(d) *Clostridium butyricum*

*37. Main source of antibiotics is which bacteria?
(a) *Bacillus* (b) *Clostridium*
(c) *Streptomyces* (d) *Rhizobium*

38. Antibiotic 'Thiothricin' is obtained from:
(a) *Bacillus subtilis* (b) *Streptomyces griseus*
(c) *Streptomyces fradiae* (d) *Bacillus brewis*

39. Which of the following diseases is not caused by bacteria?
(a) Tetanus (b) Meningitis
(c) Leprosy (d) None of these

40. 'Plague' is a disease:
(a) Viral (b) Bacterial
(c) Mycoplasmal (d) None of these

41. 'Mumps' is a disease:
(a) Viral (b) Bacterial
(c) Mycoplasmal (d) None of these

42. Tungro disease of rice is:
(a) Mycoplasmal (b) Bacterial
(c) Fungal (d) Viral

43. Which of the following diseases is not caused by bacteria?
(a) Citrus canker
(b) Blight of paddy
(c) Tundu disease of wheat
(d) Grassy shoot of sugar cane

44. Destruction of cotton is done by:
(a) *Spirochaete cytophage* virus
(b) *Spirochaete cytophage* bacteria
(c) *Clostridium botulinum*
(d) None of these

45. Low temperature storage of bacteria is:
(a) Desiccation (b) Freezing
(c) Lyophilization (d) Cryology

46. Who discovered virus? **(AFMC 1996)**
(a) Meyer (b) Ivanowski
(c) T'wort (d) Stanley

47. Viruses are nucleoproteins, was shown by:
(a) Stanley (b) Bawden and Pirie
(c) d'Herelle (d) Ivanowski

48. Viruses as '*Contagium vivum fluidum*' was said by:
(a) Meyer (b) Stanley
(c) Beijerinck (d) Chamberland

49. Bacterial filters were developed by:
(a) Meyer (b) Chamberland
(c) Burill (d) None of these

50. Which is the largest known virus?
(a) Foot and mouth disease virus
(b) Measles virus
(c) Variola virus
(d) Influenza virus

51. Tobacco mosaic virus is:
(a) Brick shaped (b) Spherical
(c) Rod shaped (d) Tadpole like

52. Which of the plant virus has DNA?
(a) TMV
(b) Bean mosaic virus
(c) Cauliflower mosaic virus
(d) None of the above

53. *E. coli* bacteria was discovered by:
(a) Waksman (b) Escherisch
(c) Safferman (d) Morris

54. Cyanophages were discovered by:
(a) d'Herelle (b) T'wort and d'Herelle
(c) Safferman and Morris (d) None of these

55. 'Lysogenic bacteria' are having:
(a) Virulent phages (b) Prophages
(c) Both (a) and (b) (d) None of these

56. The dimensions of head of bacteriophages are:
(a) 1500 Å × 950 Å (b) 950 Å × 650 Å
(c) 650 Å × 60 Å (d) 950 Å × 80 Å

57. The number of tail fibres in bacteriophages is:
(a) 2 (b) 4
(c) 5 (d) 6

58. Who discovered 'Viroids'?
(a) Stanley B. Prusiner (b) Diener
(c) Findlay (d) McCallum

59. Viroids contain: **(AIIMS 2003)**
(a) Protein only (b) DNA only
(c) RNA and protein (d) RNA only

60. Potato spindle tuber disease is caused by:
(a) Bacteria (b) Virus
(c) Viroid (d) Mycoplasma

61. Persistent infections are caused by:
(a) Bacteria (b) Viruses
(c) Viroids (d) None of these

62. Virion is:
(a) Nucleic acid of virus
(b) Antiviral agent
(c) Protein of virus
(d) Completely assembled virus outside host

63. Antiviral agents (interferons) are:
(a) Lipids (b) Proteins
(c) Alkaloids (d) Nucleic acids

64. Term 'Interferons' was given by:
(a) Diener (b) Issacs
(c) Hillemancheik (d) None of these

65. Which virus is 'Bullet shaped'?
(a) Rabies virus (b) Varicella
(c) Variola (d) Polio virus

66. 'V-Z' virus is:
(a) Variola (b) Varicella
(c) Rubeola (d) AIDS virus

67. 'AIDS' virus is called:
(a) ARV (b) HTLV
(c) HIV (d) All of these

68. AIDS virus has effect upon:
(a) Leucocytes (b) Thrombocytes
(c) Erythrocytes (d) Lymphocytes

69. 'PPLO' were first discovered by:
(a) Nocard and Raux (b) Novak
(c) Pasteur (d) None of these

70. Which character is of mycoplasma? **(Orissa JEE 2003)**
(a) Absence of cell wall
(b) Filtrability through 450 nm filters
(c) Typical colonial appearance
(d) All of the above

71. Little leaf of brinjal is caused by:
(a) Bacteria (b) Virus
(c) Mycoplasma (d) None of these

*72. Smallest known aerobic prokaryotes are:
(a) Bacteria (b) Mycoplasma
(c) Viruses (d) None of these

73. Binary fission does not occur in:
(a) Bacteria (b) Virus
(c) Mycoplasma (d) None of these

74. The bacterial cells without cell walls are called:
(a) Bacteriodes (b) Microbacterium
(c) L-form bacteria (d) No such forms

75. Which bacteria are pathogenic?
(a) Capsulated (b) Non-capsulated
(c) Both (a) and (b) (d) None of these

76. The bacterium that causes botulism belongs to the genus:
(a) *Staphylococcus* (b) *Pseudomonas*
(c) *Clostridium* (d) *Bacillus*

77. Botulism is:
(a) A disease in man
(b) A disease of plant
(c) A type of food poisoning
(d) A type of toxin formed in milk

78. The bacteria were called 'Vermes' by:
(a) Theophrastus (b) Linnaeus
(c) Leeuwenhoek (d) None of these

79. What is true about viruses? **(CPMT 1997; MPPMT 2000)**
(a) These have both DNA and RNA
(b) These have DNA or RNA
(c) These have DNA
(d) These have RNA

80. Nobel Prize was given to Waksman for discovery of: **(CBSE 2003)**
(a) Penicillin (b) Tetracycline
(c) Streptomycin (d) Chloromycetin

81. Bacteria smallest in size are:
(a) Bacillus (b) Coccus
(c) Spirillum (d) Vibrio

82. Structure formed by bacterial genome is called:
(a) Nucleozoid (b) Nucleolus
(c) Nucleoid (d) None of these

83. Gram +ve bacteria have:
(a) Thick and homogeneous cell walls
(b) As much as 90% peptidoglycan molecules
(c) Either no lipids or less than 10% lipids
(d) All of the above

84. Estimated length of DNA molecule in *E. coli* is:
(a) 1000 μ (b) 100 μ
(c) 100 Å (d) 1000 Å

85. BCG stands for:
(a) Bacillus Cancerous Gangrene
(b) Bacille Calmette Guerin
(c) Bacteria causing gangrene
(d) None of the above

86. The bacterium found in intestinal flora of human being is:
(a) *Escherichia coli* (b) *Clostridium*
(c) *Rhizobium* (d) None of these

87. Bacteria occurs in:
(a) Soil only (b) Air only
(c) Water only (d) Ubiquitous

88. Red pigment present in root nodules of legumes is:
(a) Phycoerythrin (b) Bacteriochlorophyll
(c) Leghaemoglobin (d) Bacterioviridin

89. Bacteria are plants as:
(a) Have rigid cell wall (b) Cannot move
(c) Present everywhere (d) Can multiply by fission

*90. Bacteria cannot survive in salted pickles as: **(CET Karnataka 2000)**
(a) Do not get light for reproduction
(b) Salts inhibit reproduction
(c) They get plasmolysed and killed
(d) The pickles do not contain necessary nutrients for bacteria

91. The phage that invades but does not destroy the host is called:
(a) Sexduction (b) Phycophage
(c) Virulent phage (d) Temperate phage

92. Cyanophages attack: **(MPPMT 1996)**
(a) Cyanobacteria (b) Bacteria
(c) Fungi (d) Lichens

93. Edward Jenner discovered: **(CET Karnataka 2000)**
(a) Vaccination against smallpox
(b) Vaccination against chickenpox
(c) Immunization against smallpox
(d) Immunization against chickenpox

94. Viruses are believed to be:
(a) Living organisms
(b) Non-living organisms
(c) A transitional group between living and non-living world
(d) Living organisms which have lost power of multiplication

95. Viruses were first crystallized and isolated by:
(a) Ivanowski (b) Bawden
(c) W.M. Stanley (d) Smith

96. Anton van Leeuwenhoek, the first to discover bacteria, was from: **(MPPMT 2002)**
(a) United Kingdom (b) Sweden
(c) France (d) Holland

97. What is the cause of motility in bacteria?
(a) Phototaxis (b) Chemotaxis
(c) Thermotaxis (d) Thermotropism

*98. Gram negative bacteria differ from gram positive bacteria in having: **(AFMC 1991)**
(a) Simpler wall (b) Complex wall
(c) Thicker wall (d) Wall without lipids

99. Nuclear material in bacteria is:
(a) Nucleic acid only
(b) Nucleic acid and histone protein
(c) Nucleic acid and cytoplasm
(d) All of the above

100. The bacteria which in association with some plant roots fix atmospheric nitrogen are called:
(a) *Rhizobium* (b) *Salmonella*
(c) *Pseudomonas* (d) *Bacillus*

101. H_2 donor in bacterial photosynthesis is:
(a) H_2O (b) H_2S
(c) H_2O_2 (d) H_2SO_4

102. Bacterial nucleoid consists of:
(a) One ss-DNA (b) One ds-DNA
(c) Two ds-DNA (d) Many ds-DNA

103. Which is not a component of the bacterial wall?
(a) Fats
(b) Mucopeptide
(c) Cellulose
(d) Non-cellulose polysaccharide

104. What is the general shape of the bacteria?
(a) Rod shaped (b) Spherical
(c) Spiral (d) Comma

105. Bacteria are considered to be plants because they:
(a) Cannot move (b) Have a rigid cell wall
(c) Can multiply by fission (d) Are present everywhere

106. Which one of the following fixes CO_2 in carbohydrates?
(a) *Nitrobacter* (b) *Rhodospirillum*
(c) *Rhizobium* (d) *Bacillus*

107. Bacteria differ from a virus in the presence of: **(CPMT 1993)**
(a) Cytoplasm (b) True nucleus
(c) Causing disease (d) All of these

*108. In bacteria, sex is determined by: **(Raj. PMT 1991)**
(a) Presence of pilli (b) Presence of flagella
(c) Presence of mesosomes (d) Presence of episomes

109. Which of the following cells should exhibit a successful mating?
(a) F^+ and Hfr (b) $F^+$and F^-
(c) HFr and Hfr (d) F^+ and F^+

110. Which of the following is a bacterial disease?
(a) Measles (b) Smallpox
(c) Rabies (d) Tuberculosis

111. Episomic elements are found in: **(Raj. PMT 1992)**
(a) Viruses (b) Bacterial genophore
(c) Bacterial cytoplasm (d) Mesosome

112. Which of the following is a rod-shaped bacterium?
(a) *Bacillus subtilis*
(b) *Pneumococcus pneumoniae*
(c) *Vibrio cholerae*
(d) *Streptococcus nigricans*

113. According to Cairns, the length of *E. coli* genophore is:
(a) 100 Å (b) 1000 µ
(c) 1200 Å (d) 1200 µ

114. Some bacteria are not easily killed because of:
(a) Tolerant power (b) Chitinous wall
(c) Endospore formation (d) Capsule

115. Antibiotics are mostly obtained from:
(a) Fungi (b) Viruses
(c) Bacteria (d) Angiosperms

116. *Streptomyces griseus* gives the antibiotic: **(CPMT 1991)**
(a) Streptomycin (b) Chloromycetin
(c) Terramycin (d) Polymixin

117. Milk is converted into curd by:- **(MPPMT 2002)**
(a) *Xanthomonas citri* (b) *Bacillus megatherium*
(c) *Acetobacter aceti* (d) None of these

*118. Rickettsiae is a group of:
(a) Viruses (b) Bacteria
(c) Micro-organisms (d) PPLO

119. Curved or comma-shaped bacterium of cholera is termed:
(a) Coccus (b) Bacillus
(c) Spirillum (d) Vibrio

120. In bacteria:
(a) DNA is double-stranded and ringed
(b) DNA is scattered
(c) DNA is enclosed in nucleus
(d) DNA is 4 in number in nucleus

121. Which of the following represents obligate anaerobes? **(CPMT 1991)**
(a) *Spirogyra* (b) *Pisum sativum*
(c) Onion (d) Methane bacteria

122. The following bacterium is associated with denitrification:
(a) *Azotobacter* (b) *Rhodospirillum*
(c) *Pseudomonas* (d) *Rhizobium*

123. If a bacterial cell divides in every 20 minutes, how many bacteria will be formed in two hours?
(a) 4 (b) 8
(c) 16 (d) 64

124. Crown gall disease is caused by: **(CBSE 1990)**
(a) Bacteria (b) Virus
(c) Fungi (d) Mycoplasma

125. Bacteria that are responsible for fermentation of dairy milk are: **(BAM 1991)**
(a) *Acetobacter* (b) *Rhizobium*
(c) *Lactobacillus* (d) *Hay bacillus*

126. A compound which is produced by an organism and inhibits the growth of other organism is called:
(a) Antiallergic (b) Antibiotic
(c) Antiseptic (d) Anticoagulant

127. *Nitrosomonas* converts: (CPMT 1993)
(a) $NH_3 \rightarrow$ Nitrite (b) $N_2 \rightarrow NH_3$
(c) Nitrite → Nitrate (d) $NH_3 \rightarrow N_2$

128. Who discovered transformation in *Diplococcus* by a cell free extract of heat killed transformant?
(a) Frobischer (b) Brown
(c) Griffith (d) McLeod

129. Formation of vinegar from alcohol is caused by:
(a) *Clostridium* (b) *Bacillus subtilis*
(c) *Azotobacter* (d) *Acetobacter aceti*

130. Spherical bacteria arranged in uniseriate chains are called:
(a) *Coccus* (b) *Bacillus*
(c) *Streptococcus* (d) *Staphylococcus*

131. Bacterial ribosomes are called: (Re. Ex. CPMT 1991)
(a) Polyribosomes (b) Autosomes
(c) Mitochondria (d) Ribosomes

132. Bacteria lack: (Re. Ex. CPMT 1991)
(a) Cell wall (b) Plasma membrane
(c) Mitochondria (d) Ribosomes

133. Some chemosynthetic bacteria obtain energy by oxidising: (BHU 1991)
(a) SO_2 (b) CO_2
(c) N_2 (d) H_2S

134. Who discovered conjugation in bacteria? (MPPMT 1990, 2000)
(a) Lederberg and Tatum (b) Griffith
(c) Jacob and Wollman (d) Zinder and Lederberg

135. Different flavours in tea and tobacco are due to:
(a) Bacterial fermentation (b) Mechanical processes
(c) Activity of moulds (d) Activity of viruses

136. Pasteurized milk is: (MPPMT 1993)
(a) Free from pathogenic bacteria
(b) Not free from bacteria
(c) Sterile and will not turn sour under any condition
(d) None of the above

137. Tetracycline is obtained from:
(a) *S. griseus* (b) *S. aureofaciens*
(c) *S. ramosus* (d) *S. fradiae*

138. Bacterium is favoured in the studies on molecular biology because:
(a) It has a single chromosome
(b) Of faster multiplication
(c) It has histone-free DNA
(d) It is a prokaryote

139. Citrus canker is caused by: (MPPMT 1990; 2002)
(a) *Pseudomonas scalaris*
(b) *Xanthomonas oryzae*
(c) *Xanthomonas citri*
(d) *Pseudomonas solanacearum*

*140. Interferons are useful in controlling:
(a) T.B. (b) Cancer
(c) Malaria (d) Blood pressure

141. Bacterial cells differ from other plants in that they lack:
(a) Respiratory assemblies
(b) Well-defined nucleus
(c) Photosynthetic pigments
(d) Cytoplasm and endoplasmic reticulum

142. Which of the following is not a characteristic of bacteria?
(a) N_2 fixation (b) Presence of plastids
(c) Fermentation (d) Parasitic nature

143. Which of the following is size of bacteria? (CPMT 1991)
(a) 2–10 μ (b) 10–15 μ
(c) 50–100 μ (d) 100–200 μ

144. There is no alternation of generations in *Escherichia coli* because there is: (CBSE 1992)
(a) No syngamy (b) No reduction division
(c) No conjugation (d) None of these

145. Bacterium which causes tuberculosis: (Raj. PMT 1992)
(a) *Salmonella* (b) *Mycobacterium*
(c) *Diplococcus* (d) *Streptomyces*

146. Pasteurization makes food stuffs free from: (BHU 1990)
(a) All vegetative forms of bacteria
(b) Vegetative forms of all pathogenic microbes
(c) All living organisms
(d) All bacteria

147. Which of the following is the most resistant stage in bacteria?
(a) Endospore (b) Conidia
(c) Gonidia (d) Oidia

148. Germ theory of disease was proposed by: (AFMC 1990)
(a) Leeuwenhoek (b) Robert Koch
(c) Bold and Tippo (d) De Bary

*149. Photosynthetic bacteria have:
(a) Chloroplasts and PS-II
(b) Chromoplasts
(c) Chromatophores and PS-I
(d) Leucoplasts

150. Nitrogen fixation of soil is assisted by: (CPMT 1997)
(a) *Thiobacillus* (b) *Nitrosomonas*
(c) *Nitrobacter* (d) *Azotobacter*

151. Microbe which is harmful and enters the human body to cause disease is called?
(a) Saprophyte (b) Symbiont
(c) Pathogen (d) Commensal

152. The product of sexuality or fertilization in bacteria is: (CBSE 1990)
(a) 2x-Zygote (b) 2x-Oospore
(c) Merozygote (d) Coenozygote

153. Genetic recombination in bacteria was discovered by (or first indication of sexuality in bacteria was given by):
(a) Lederberg and Tatum (b) Griffith
(c) Wollmen (d) Zinder

154. Bacteria resemble plants in:
(a) The presence of wall and phagotrophy
(b) Absence of wall and cladotrophy
(c) Presence of wall and osmotrophy
(d) Presence of wall and phototrophy

155. Gram stain is: (CPMT 1991)
(a) Stain produced out of a gram
(b) A trade mark

(c) A staining technique developed by the Dutch scientist 'Gram'
(d) Chemical for differentiation of bacteria

156. Folds of plasma membrane in bacterial cells are known as: **(MPPMT 1997)**
(a) Episomes (b) Mesosomes
(c) Spherosomes (d) Acrosomes

157. Which of the following is a correct statement?
(a) All bacteria are parasites
(b) All bacteria are saprophytes
(c) Many bacteria are heterotrophs
(d) Many bacteria are autotrophs

***158.** Enteric bacterial food poisoning is caused by:
(a) *E. coli* (b) *Xanthomonas citri*
(c) *Clostridium botulinum* (d) *Clostridium perfringens*

159. Sterilization in an autoclave: **(CPMT 1993)**
(a) Destroys the bacterial activity
(b) Denatures the enzymes
(c) Both (a) and (b)
(d) None of the above

160. Little leaf of brinjal is caused by:
(a) Virus (b) Fungus
(c) Mycoplasma (d) Algae

161. Neomycin is obtained from:
(a) *Streptomyces griseus* (b) *S. fradiae*
(c) *Aspergillus clavatus* (d) *Aspergillus fumigatus*

162. Bacteria responsible for nitrification come under the following groups:
(a) Coccus (b) Comma
(c) Bacillus (d) Spiral

163. Bacteria differ from other fungal groups in one of the following:
(a) Cell wall of fungal cellulose
(b) Heterotrophic nutrition
(c) Binary fission
(d) Absence of chlorophyll

164. What peculiar amino acid is present in the cell walls of bacteria?
(a) Calcium dipicolinate (b) Diaminopalmate
(c) Glutamate (d) None of these

165. Staphylococcus bacterium is a:
(a) Chain-like colony (b) Plate-like colony
(c) Bunch-like colony (d) Cube-like colony

166. Bacteria which are smallest in size are:
(a) Cocci (b) Vibrio
(c) Bacilli (d) Spirilla

167. Myolic acid is present in the cell wall of pathogen causing:
(a) Cholera (b) Tuberculosis
(c) Tetanus (d) Diphtheria

168. Plasmids are: **(Raj. PMT 1991; Orissa JEE 2003)**
(a) Small coils of DNA
(b) Small coils of RNA
(c) Small particles of RNA plus protein
(d) Small photosynthetic particles of bacteria

169. Nitrifying bacteria convert:
(a) Nitrogen into nitrates
(b) Ammonia or ammonium compounds into nitrates
(c) Nitrate into nitrogen
(d) Carbon dioxide into carbohydrates

170. The process of transfer of genetic material of one bacterium (donor) to the other bacteria with the help of bacteriophage is: **(BHU 1991)**
(a) Translation (b) Transduction
(c) Transcription (d) Transformation

171. Broad spectrum antibiotic is that which:
(a) Acts on both pathogens and hosts
(b) Acts on all bacteria and viruses
(c) Acts on a variety of pathogenic micro-organisms
(d) Is effective in very small amounts

172. The equipment employed for sterilizing glassware and culture media is known as:
(a) Incubator (b) Dehumidifier
(c) Autoclave (d) Dry oven

173. The term Cyanobacterium refers to: **(BHU 1991)**
(a) Yeast (b) Blue-green algae
(c) Photosynthetic bacteria (d) Nitrogen-fixing bacteria

174. Bacterial ribosomes lie:
(a) In cytoplasm (b) On nuclear membrane
(c) On the cell wall (d) On endoplasmic reticulum

175. Denitrifying bacteria convert:
(a) Nitrate to free nitrogen (b) Nitrogen to ammonia
(c) Ammonia to nitrate (d) Nitrite to nitrate

176. Which of the following diseases is caused by bacteria?
(a) Arthritis (b) Amoebic dysentery
(c) Beri-beri (d) Diphtheria

177. The production of nitrates from ammonia through *Nitrosomonas* is called:
(a) Nitrification (b) Ammonification
(c) Nitrogen fixation (d) Denitrification

178. The process of nitrogen fixation by *Rhizobium leguminosarum* in root nodules of legumes is known as:
(a) Abiotic nitrogen fixation
(b) Non-symbiotic nitrogen fixation
(c) Symbiotic nitrogen fixation
(d) Autotrophic nitrogen fixation

179. Bacterial cell membrane is made up of:
(a) Phospholipoprotein and fat
(b) Cellulose
(c) Fat
(d) Chitin

***180.** All life on earth derives its energy directly or indirectly from sun except: **(CBSE 1991)**
(a) Mushroom and mould (b) Chemosynthetic bacteria
(c) Symbiotic bacteria (d) Pathogenic bacteria

181. Bacteria which directly convert atmospheric nitrogen into nitrogen compounds are called: **(AFMC 1996)**
(a) Denitrifying bacteria (b) Putrefying bacteria
(c) Nitrogen-fixing bacteria (d) Nitrifying bacteria

182. A bacterial cell divides once in every minute and takes one hour to fill a cup. How much time will it take to fill half the cup? **(CET Karnataka 2001)**
(a) 60 minutes (b) 29 minutes
(c) 59 minutes (d) 30 minutes

*183. *Haemophilus influenzae* causes:
(a) Bronchitis (b) Influenza
(c) Meningitis (d) Whooping cough

184. Plasmids are: (CPMT 1993)
(a) Virus
(b) A part of mycoplasma
(c) Extranuclear genetic material of bacteria
(d) Genetic material of plants

185. Mycoplasma differs from viruses in being sensitive to:
(a) Sugars (b) Penicillins
(c) Amino acids (d) Tetracyclines

186. It is important to boil surgical instruments before using them in an operation so as to:
(a) Kill all pathogens infecting the instruments
(b) Facilitate the handling of instruments
(c) Enable the patient to feel warmth and comfort
(d) Kill all pathogens at the place of operation

187. Plasmids are:
(a) Viruses
(b) New type of micro-organisms
(c) Extrachromosomal genetic elements of bacteria
(d) Genetic elements of bacteria

188. Which of the following causes Diphtheria?
(a) *Corynebacterium* (b) *Pseudomonas*
(c) *Bacillus diphtheriae* (d) *Salmonella typhosa*

189. Transformation experiments using *Pneumococcus* bacteria led to the hypothesis that:
(a) RNA is the transfer link between DNA and protein synthesis
(b) Chromosomes are made up of DNA
(c) DNA is the genetic substance
(d) Bacteria have sexual reproduction

190. The role of bacteria is not significant in the production of: (Re. Ex. CPMT 1991)
(a) Vitamin B-complex (b) Cheese
(c) Baked bread (d) Coffee

191. An organism lacking chlorophyll but able to carry on photosynthesis of organic matter has been found among which one of the following?
(a) Bacteria (b) Fungi
(c) Viruses (d) Bacteriophage

192. Camel, cattle and sheep digest cellulose by virtue of:
(a) Their enzymes
(b) Symbiotic *E. coli*
(c) Symbiotic protozoa and bacteria
(d) Symbiotic viruses and nematodes

193. The main difference between gram +ve and gram –ve bacteria is of: (CBSE 1990)
(a) Cell wall
(b) Composition of protoplasm
(c) Occurrence of free cations and anions
(d) Genophore and physiology

194. Which of the following is a food poisoning and gas forming bacterium?
(a) *Salmonella typhosa* (b) *Clostridium botulinum*
(c) *Shigella boydiae* (d) *Escherichia coli*

195. If all the bacteria and fungi of the world are destroyed then:
(a) All living things will become immortal and there will be no disease left
(b) We shall be unable to obtain any antibiotics
(c) The soil will gradually become depleted of all nitrogen
(d) The world will become packed with dead bodies and excretions of all kinds of living organisms

196. The nitrifying bacteria that convert the ammonia to nitrates are:
(a) *Azotobacter*
(b) *Rhizobium leguminosarum*
(c) *Thiobacillus denitrificans*
(d) *Nitrosomonas and nitrobacter*

197. A free living bacterium capable of fixing atmospheric nitrogen is:
(a) *Azotobacter* (b) *Streptococcus*
(c) *Staphylococcus* (d) None of these

198. Colourless, unicellular, cell wall bound spherical or rod shaped micro-organisms usually smaller than 5 microns in size, which lack an organised nucleus are called:
(a) Virus (b) Bacteria
(c) Cyanobacteria (d) Rickettsiae

199. Bacteria without flagella are known as:
(a) Monotrichous (b) Peritrichous
(c) Lophotrichous (d) Atrichous

200. Lipids and proteins are the components of cell walls in: (AFMC 1990)
(a) Gram positive bacteria (b) Gram negative bacteria
(c) Gram variable bacteria (d) All fungal cells

201. Bacteria bearing flagella over the body are called: (MPPMT 1990; Raj. PMT 1991)
(a) Monotrichous (b) Peritrichous
(c) Cephalotrichous (d) Atrichous

202. Nodules with nitrogen-fixing bacteria are present in:
(a) Mustard (b) Wheat
(c) Gram (d) Cotton

203. Which of the following is not true for bacterial cell wall? (AIIMS 1991)
(a) It is made up of mucopeptide.
(b) It is not antigenic
(c) It gives shape to bacteria
(d) It is not stainable with simple dyes

204. Some diseases caused by bacteria are:
(a) Measles, mumps, malaria
(b) Tetanus, typhoid, tuberculosis
(c) Smallpox, sleeping sickness, syphilis
(d) Pneumonia, poliomyelitis, psittacosis

205. Streptomycin is produced by:
(a) *Streptomyces venezuelae* (b) *Streptomyces griseus*
(c) *Streptomyces scoleus* (d) *Streptomyces fradiae*

206. Pilli in bacteria are used for: (Raj. PMT 1990)
(a) Asexual reproduction (b) Prey hunting
(c) Locomotion (d) Sexual contact

207. Who was the first to isolate streptomycin?
(a) Twort (b) A. Fleming
(c) S. Waksman (d) R. Koch

208. Botulism means:
(a) Bottle fermentation
(b) Skin disease
(c) Canned food poisoning by *Clostridium*
(d) Plant disease

209. *Streptomyces venezuelae* is used to obtain:
(a) Chloromycetin (b) Streptomycin
(c) Tetracycline (d) Aureomycin

210. The chief components of a bacterial cell wall are:
(a) Amino acids and polysaccharides
(b) Cellulose and chitin
(c) Cellulose and pectin
(d) Cellulose and carbohydrates

211. The process of the decay of the remains and excreta of the animals and plants is known as:
(a) Denitrification (b) Nitrification
(c) Nitrogen fixation (d) Ammonification

212. We can keep food for longer duration in cold storage than in ordinary cupboard because:
(a) Low temperature causes plasmolysis
(b) Insects cannot cause infection
(c) Bacterial multiplication is greatly increased
(d) Bacterial multiplication is completely prevented

213. Asexual reproductive structure in bacteria is known as:
(a) Akinete (b) Exospore
(c) Endospore (d) Heterocyst

214. Meningitis, a disease which is responsible for damaging the membrane of brain, is caused by:
(a) A fungus (b) *Bacillus*
(c) *Neisseria* (d) *Bordetella*

215. Triple antigen or DPT is meant for:
(AIIMS 1990; DPMT 1997)
(a) A vaccine against malaria, typhoid and cancer
(b) Mixture of viruses that causes tetanus, diphtheria and whooping cough
(c) A vaccine against polio, rabies and hepatitis
(d) A vaccine against tetanus, whooping cough and diphtheria

216. Bacteria commonly reproduce vegetatively by:
(CPMT 2003)
(a) Binary fission (b) Conjugation
(c) Oidia (d) Budding

217. The bacterial cell wall is composed of: **(AMU 1992)**
(a) Cellulose (b) Lipid
(c) Chitin (d) Glycopeptide/Mucopeptide

218. Bacteria cannot survive in a highly salted pickle because:
(a) They get plasmolysed and are consequently killed
(b) The pickle does not contain nutrients necessary for bacteria to live
(c) Salt inhibits reproduction
(d) Bacteria do not get enough light for reproduction

219. Viruses are considered to be:
(a) Living organisms
(b) Non-living objects
(c) A transitional group between non-living and living
(d) Living organisms which have lost power of multiplication

220. The virus responsible for AIDS is an example of a (an):
(MPPMT 1993)
(a) Adeno virus (b) Mosaic virus
(c) T-even virus (d) Retrovirus

221. Mosaic of sugar cane is caused by:
(a) Bacteria (b) Fungi
(c) Algae (d) Virus

222. Genetic material of TMV is:
(a) ss-DNA (b) ds-DNA
(c) ss-RNA (d) ds-RNA

223. What low molecular weight proteins are produced by a host cell in response to viral infection which protects a pre-infected cell from a viral infection?
(a) Antibodies (b) Phytotoxins
(c) Interferons (d) Phytoalexins

224. Longest known virus is:
(a) $\phi \times 174$ (b) TMV
(c) Citrus tristeza (d) T_1 phage

225. Which of the following statements is correct?
(a) Viruses do not contain nucleic acid
(b) All viruses contain DNA
(c) All viruses contain RNA
(d) Some viruses contain DNA and some contain RNA

226. Infective nature of tobacco mosaic disease was discovered by:
(a) Ivanowsky (b) Meyer
(c) Beijerinck (d) Stanley

227. AIDS is caused by virus:
(a) HTLV-III (or LAV or ARV-2)
(b) SV-40
(c) $\phi \times 174$
(d) All of the above

228. Which of these are viral diseases?
(a) Influenza, mumps and measles
(b) Smallpox and chickenpox
(c) Polio and hydrophobia
(d) All of the above

229. The smallest known agent of a plant disease is:
(a) Virus (b) Viroid
(c) Bacteria (d) Mycoplasma

230. How many genes are present in the simplest virus?
(Raj. PMT 1990)
(a) One (b) Five
(c) Eight (d) Nine

231. Leaf curl disease of potato is caused by: **(MPPMT 2002)**
(a) Bacteria (b) Virus
(c) Fungi (d) Mycoplasma

232. Which of the following was used by Hershey and Chase to prove that DNA is the chemical basis of heredity?
(a) Dahlia mosaic virus (b) T_2-bacteriophage
(c) Tobacco mosaic virus (d) Cauliflower mosaic virus

233. One of the following is an example of DNA containing plant virus:
(a) Cauliflower mosaic virus
(b) Tobacco mosaic virus
(c) Potato mosaic virus
(d) Tomato mosaic virus

234. First animal pathogenic virus was discovered by:
(a) Ivanowski (b) Stanley
(c) Loeffler and Frosch (d) Adolph Meyer

235. Banana bunchy top is caused by:
(a) *Mycoplasma* (b) *Deuteromycetes*
(c) *Xanthomonas* (d) Viruses

236. Antiviral substance produced by many vertebrates in response to viral infection for resisting the multiplication of viruses is known as: (MPPMT 1996)
(a) Virion (b) Interferon
(c) Antivirin (d) Antigen

237. A single stranded DNA molecule is the genetic material of bacteriophage: (BHU 1992)
(a) T_2 (b) T_4
(c) $\phi \times 174$ (d) λ (lambda)

238. Our crops suffer from many diseases. Indicate the disease caused by a virus: (BHU 1990)
(a) Potato mosaic (b) Citrus canker
(c) Brown rot of potato (d) Leaf spot of cotton

239. Which of the following is not correct for viruses?
(a) They are made up of nucleic acids and proteins
(b) They can multiply in host cytoplasm
(c) They can grow in dilute sugary solution
(d) They cannot utilise O_2

240. Viroids have:
(a) Single stranded RNA not enclosed by protein coat
(b) Single stranded DNA enclosed by protein coat
(c) Double stranded DNA enclosed by protein coat
(d) Double stranded RNA not enclosed by protein coat

241. Bacteriophage consists of: (BHU 1992)
(a) Carbon and nitrogen (b) DNA or RNA
(c) Nucleoprotein (d) Proteins
(e) Protein and lipids

242. Coliphage $\phi \times 174$ contains:
(a) ss-DNA (b) ss-RNA
(c) ds-RNA (d) ds-DNA

243. Detailed study of bacteriophage was made by:
(a) Ivanowski (b) Stanley
(c) Twort (d) d'Herelle

244. Virion refers to:
(a) Capsid of virus (b) Dead virus
(c) Nucleic acid of virus (d) Complete form of virus

245. Infective portion of a virus is nucleic acid, was discovered by:
(a) d'Herelle (b) Hershey and Chase
(c) Stanley (d) Ivanowski

246. Smallpox virus has:
(a) ss-DNA (b) ds-DNA
(c) ss-RNA (d) ds-RNA

247. Viruses have:
(a) Chromosomes (b) Ribosomes
(c) Nucleic acids (d) Carbohydrates

248. A stage following infection of a cell by a virus during which the presence of virus particles cannot be made out:
(a) Infection phase (b) Eclipse phase
(c) Maturation phase (d) Lysogenic phase

249. Coliphages contain: (CPMT 1991)
(a) RNA (b) DNA
(c) DNA/RNA (d) DNA as well as RNA

250. The best evidence which supports that viruses are living is that the viruses:
(a) Are made up of common chemicals
(b) Duplicate themselves
(c) Cause diseases
(d) Penetrate a cell membrane

251. Capsid refers to:
(a) Nucleic acid of virus
(b) Protein coat of virus particles
(c) Carbohydrate part of virus
(d) None of the above

252. Plant virus (TMV) was first isolated in crystalline form (or crystallised) by:
(a) Ivanowski (b) Stanley
(c) Miller (d) Sabin
(e) Bawden (f) Beijerinck

253. Nucleic acid present in coliphage and other virus is:
(a) DNA only (b) RNA only
(c) DNA or RNA (d) DNA and RNA

254. Mycophages have:
(a) ss-RNA (b) ds-RNA
(c) ss-DNA (d) ds-DNA

255. Chickenpox is caused by:
(a) Bacteria (b) Bacteriophage
(c) *Varicella* virus (d) Pox virus

256. Who discovered virus? (CPMT 1992)
(a) Leeuwenhoek (b) A.P. de Candolle
(c) Demitrio Ivanowski (d) Beijerinck

257. Which of the following is not a viral disease?
(a) Red rot of sugar cane (b) Tobacco mosaic
(c) Leaf curl of papaya (d) Tristeza disease of *Citrus*

*258. Viruses usually infect whole plant except:

Or

Which region of an infected vascular plant remains free from viruses?

Or

The virus-free clones can be obtained from:
(a) Root (b) Leaves
(c) Stem (d) Apical meristems

259. A naked RNA particle causing the symptoms like that of a virus disease is known as: (DPMT 1991)
(a) Viroid (b) Virion
(c) Viral (d) None of these

260. In cyanophages, the genetic material is:
(a) DNA (b) RNA
(c) Both DNA and RNA (d) Proteins

261. Which virus (among following) was isolated first?
(a) $\phi \times 174$ (b) Pox virus
(c) TMV (d) LPP-1

262. Plant viruses are mostly:
(a) Proteins (b) Nucleoproteins
(c) Mineral salts (d) Fats and minerals

263. Viruses can multiply in: (BHU 1992)
(a) Bacteria only (b) All living cells
(c) Specific living cells (d) Rotten food

264. Viruses are commonly transmitted in plants through:
(a) Wind (b) Water
(c) Sucking insects (d) Animals

265. Which of the following diseases are known to be caused by viruses? (In this item one or more of the answers given may be correct. Decide which are correct and mark the answer sheet according to the code.)
1. Burkitt's lymphoma
2. Adult T-Cell leukemia
3. Phenyl ketonuria
Code: **(MPPMT 1993)**
(a) 1, 2 and 3 are correct
(b) Only 1 and 2 are correct
(c) Only 2 and 3 are correct
(d) Only 1 and 3 are correct

266. Cryptogram of TMV is:
(a) R/2 : 2/5 : E/E : X/S (b) R/1 : 2/5 : E/E : S/X
(c) R/1 : 1/8 : S/S : S/Ap (d) R/1 : 2/7 : E/E : S/X

267. Hydrophobia is caused by a: **(CPMT 1991)**
(a) Bacterium (b) Fungus
(c) Virus (d) Protozoan

268. Which of the following viruses is devoid of protein coat with their entire body constituted by only RNA?
(a) Tobacco mosaic virus (TMV)
(b) Potato spindle tuber virus (PSTV)
(c) Polyoma virus
(d) Mumps virus

269. AIDS virus contains:
(a) RNA with protein (b) DNA with protein
(c) RNA without protein (d) Only DNA

270. Which of the following is true of viruses? (or interesting feature of the viruses is that)
(a) They multiply in host cells only
(b) They behave as if they are plants
(c) They are made up of proteins only
(d) They occur only inside bacteria

271. In phage (or plaque) culture: **(Pondicherry 1992)**
(a) Whole of the virus enters the bacteria and multiplies
(b) Only DNA of the virus enters and multiplies
(c) Only protein of the virus enters and multiplies
(d) Capsid and envelope enter and multiply

272. Which of the following characters justify the living nature of viruses?
(a) Multiplicity
(b) Mutability
(c) Capability of protein synthesis
(d) All of the above

273. The viruses that infects bacteria, are made up of: **(AIIMS 1997)**
(a) DNA only (b) RNA only
(c) Protein only (d) Both (a) and (c)

274. Average size range of virus is:
(a) 10–30 nm (b) 20–300 nm
(c) 100–1000 nm (d) 1–10 nm

275. Microbiology deals with unicellular microscopic organisms which include:
(a) Bacteria (b) Viruses
(c) Algae and fungi (d) All of these

276. The first to isolate plant viruses was: **(BHU 1992)**
(a) W.M. Stanley (b) R.M. Smith
(c) D. Ivanowski (d) F.C. Stakman

277. Virus and bacteriophage are made up of:
(a) Protein (b) Nucleoprotein
(c) Lipoprotein (d) DNA and RNA

278. Caulimoviruses are a group of viruses which have: **(MPPMT 1990)**
(a) Double stranded RNA (b) Single stranded RNA
(c) Single stranded DNA (d) Double stranded DNA

279. Viruses are essentially made up of:
(a) Proteins and nucleic acids
(b) Proteins and carbohydrates
(c) Lipids and nucleic acids
(d) Starch, protein and lipids

280. Who crystallised and isolated viruses for the first time?
Or
The credit for crystallisation of virus goes to: **(CPMT 1991)**
(a) W.M. Stanley (b) K.M. Smith
(c) D. Ivanowski (d) F.C. Bawden
(e) Louis Pasteur (f) S. Luria

281. Which does not contain both DNA and RNA together?
Or
Which among the following contains only one type of nucleic acid?
(a) Yeast (b) Bacteria
(c) Mycoplasma (d) Virus

282. The group of viruses which attack blue-green algae are termed?
(a) Bacteriophages (b) Cyanophages
(c) Mosaic viruses (d) Phages only

283. A natural stage of virus which is capable of infection is: **(Raj. PMT 1992)**
(a) Viroid (b) Virusoid
(c) Virion (d) Virus particle

284. Animal viruses have an inner core of: **(Raj. PMT 1991)**
(a) DNA/RNA (b) RNA only
(c) Phosphoproteins (d) DNA only

285. The development of clear translucent areas on an agar plate which contains phage particles and bacteria are called?
(a) Bacteriophages (b) Transparencies
(c) Plaques (d) Holes

286. Which of the following diseases is caused by a virus?
(a) Malaria (b) Influenza
(c) Diphtheria (d) Syphilis

287. Which of the following diseases is caused by a virus?
(a) Tuberculosis (b) Typhoid
(c) Polio (d) Diphtheria

288. Chemolithotrophs are organisms in which growth depends upon oxidisable substances like:
(a) Nitrite (b) Ammonium ions
(c) Both (a) and (b) (d) None of these

289. Which of the following antibiotic inhibits cell wall synthesis in bacteria?
(a) Penicillin (b) Chloramphenicol
(c) Streptomycin (d) None of these

290. Viruses that parasitise bacteria are known as:
(a) Mosaics (b) Mutons
(c) Bacteriophages (d) All of these

291. The DNA of the bacteria is not enclosed within a nuclear membrane, hence it is known as:
(a) Chromatin body (b) Nucleoid
(c) Both (a) and (b) (d) None of these

292. Viruses are:
(a) Dead cells
(b) Infective micro-organisms
(c) Non-infective micro-organisms
(d) None of the above

293. In green sulphur bacteria the reaction centre pigments of photosynthesis are:
(a) Bacteriochlorophyll-a (b) Bacteriochlorophyll-c
(c) Bacteriochlorophyll-d (d) All of these

294. A mutant strain without capsule is known as:
(a) Avirulent type (b) Non-pathogenic
(c) Virulent type (d) Both (a) and (b)

295. Some viruses multiply as soon as they enter the host cell, resulting in lysis or breakdown of the host cell. Such viruses are called:
(a) Prophage (b) Lysogenic viruses
(c) Lytic viruses (d) None of these

296. The intact virus unit or infectious particle is called:
(a) Capsomers (b) Virion
(c) Bacteriophage (d) Muton

297. The electron transport system of bacteria is located in:
(a) Mitochondria (b) Plasma membrane
(c) Cristae (d) All of these

298. Viruses do not have an independent metabolism because:
(a) They do not possess enzyme systems and protein synthesis machinery
(b) They cannot multiply outside a living cell
(c) Both (a) and (b)
(d) None of the above

299. Sex-factor in bacteria is: (CBSE 1996)
(a) F-replicon (b) Chromosomal replicon
(c) RNA (d) Sex-pilus

300. In bacterial chromosomes the nucleic acid polymers are: (CBSE 1996)
(a) Of two types—DNA and RNA
(b) Linear DNA molecule
(c) Circular DNA molecule
(d) Linear RNA molecule

301. Interferons are: (CBSE 1996; AFMC 2002)
(a) Antiviral proteins (b) Complex proteins
(c) Antibacterial proteins (d) Anticancer proteins

302. Genetically engineered bacteria have been used in commercial production of: (CBSE 1996)
(a) Thyroxine (b) Testosterone
(c) Human insulin (d) Melatonin

303. Causative organism of plague is: (AFMC 1996)
(a) *Avian tuberculosis*
(b) *Clostridium welschi*
(c) *Pasteurella pestis*
(d) *Corynebacterium diphtheriae*

304. Animal viruses usually have: (AFMC 1996)
(a) DNA and RNA (b) DNA or RNA
(c) DNA (d) RNA

305. Many bacteria bear minute structures on their cell wall. These are called: (AFMC 1996)
(a) Hair (b) Flagella
(c) Cilia (d) Pilli

306. Tuberculosis is caused by: (AFMC 1996; CET J&K 2002)
(a) *Salmonella* (b) *Diplococcus*
(c) *Mycobacterium* (d) *Streptomyces*

307. The bacteria which convert nitrate into molecular nitrogen are called as: (MPPMT 1996)
(a) Nitrifying bacteria (b) Methano bacteria
(c) Diazotrophic bacteria (d) Denitrifying bacteria

308. Penicillin is useful in controlling:
(a) Gram +ve bacteria (b) Gram –ve bacteria
(c) Both (a) and (b) (d) None of these

309. Cyanophages attack: (MPPMT 1996)
(a) Cyanobacteria (b) Bacteria
(c) Fungi (d) Lichens

310. An antiviral chemical produced by the animal cell is: (MPPMT 1996)
(a) Virion (b) Interferon
(c) Repressor protein (d) Hormone

311. Antibiotics are: (MPPMT 1996)
(a) Herbicides (b) Pesticides
(c) Macrobicides (d) Bactericides

312. The bacterial genome contains: (MPPMT 1996)
(a) DNA and histone (b) DNA or histone
(c) DNA without histone (d) Neither DNA nor histone

313. The filterable property of tobacco mosaic virus (TMV) was shown by: (MPPMT 1996)
(a) Ivanowski (b) Beijerinck
(c) Stanley (d) Winogradsky

314. The smallest free-living organism is: (MPPMT 1996)
(a) Virus (b) Mycoplasma
(c) Cyanobacteria (d) Bacteria

*315. *Nif* genes occur in: (MPPMT 1996)
(a) *Rhizobium* (b) *Penicillium*
(c) *Aspergillus* (d) *Streptococcus*

316. Phages that show lysogenic cycle are called: (MPPMT 1997)
(a) Temperate phages (b) Virulent phages
(c) Avirulent phages (d) Lytic phages

317. Organisms without any specific shape are: (MPPMT 1997)
(a) Mycoplasma (b) Bacteria
(c) Viruses (d) Cyanobacteria

318. One of the major components of bacterial cell wall is a polymer called: (MPPMT 1997)
(a) Peptidoglycan (b) Cellulose
(c) Chitin (d) Xylan

319. In many bacteria, the cell membrane becomes invaginated and folded to form: (MPPMT 1997)
(a) Cristae (b) Mesosomes
(c) Fimbriae (d) Pilli

320. The length of the bacterial flagellum ranges between:
(a) 10–20 μ (b) 1–2 μ
(c) 40–50 μ (d) 4–5 μ

321. The size of a bacterial ribosome is:
(a) 80 Å (b) 100 Å
(c) 70 Å (d) 180 Å

322. A bacterial cell weighs around:
(a) 2.0 picogram (b) 0.0002 picogram
(c) 0.2 picogram (d) 0.00002 mg

323. The percentage of nucleic acids in bacterium is about:
(a) 4.5% (b) 2.5%
(c) 3.6% (d) 3.0%

324. The apparatus chemostat is used for:
(a) Growing bacteria on soil
(b) Chemical analysis of bacteria
(c) Continuous bacterial culture
(d) None of the above

325. The length of DNA molecule in *E. coli* is about:
(a) 45000 Å (b) 1.5 mm
(c) 150 μ (d) 1500 nm

326. The most suitable pH for the growth of bacteria is:
(a) 8 (b) 7
(c) 5 (d) 5.6

327. The Hfr strains are:
(a) Super males (b) Super females
(c) Normal males (d) Normal females

328. The spirochaetes move by:
(a) Flagella (b) Pseudopodia
(c) Gliding (d) Fimbriae

329. Heating of milk and other substances at 65°C and their sudden cooling is known as: (CPMT 1991)
(a) Sterilization (b) Pasteurization
(c) Preservation (d) Fermentation

330. Cellulose present in the food of grazing animals is:
(a) Digested by the intestinal bacteria
(b) Digested by the animal itself
(c) Digested partly by the animal and partly by the bacteria
(d) Passed out indigested

331. Wine turns sour because of:
(a) Heat (b) Aerobic bacteria
(c) Anaerobic bacteria (d) Exposure to light

332. Asexual reproductive structure in bacteria is known as:
(a) Akinete (b) Heterocyst
(c) Endospore (d) Exospore

333. The bacterium that commonly lives in human intestine is:
(a) *Vibrio cholerae* (b) *Bacillus anthracis*
(c) *Corynebacterium* (d) *Escherichia coli*

334. Vinegar is obtained from sugar by: (BAM 1991)
(a) *Lactobacillus* (b) *Acetobacter*
(c) *Nitrosomonas* (d) *Salmonella*

335. The hydrogen donor in bacterial photosynthesis is: (BAM 1991)
(a) H_2O (b) H_2S
(c) H_2SO_4 (d) HCl

336. Diaminopimelic acid and muramic acid are constituents of cell walls of:
(a) Higher plants (b) Fungi
(c) Bacteria (d) Bacteriophages

337. When the flowers become green due to virus infection it is described as:
(a) Enations (b) Molting
(c) Virescence (d) None of these

338. LPP-1 is a:
(a) Lipovirus (b) Bacteriophage
(c) Cyanophage (d) Lambda phage

339. Which of the following is a viral disease? (BAM 1991)
(a) Red rot of sugar cane (b) Leaf roll of potato
(c) Wilt of cabbage (d) Damping off disease

340. Which is the method followed for virus elimination in plants? (BAM 1991)
(a) Antibiotic treatment
(b) Shoot apex culture
(c) Root apex culture
(d) Spraying bordeaux mixture

341. The shape of rabies virus is:
(a) Icosahedral (b) Bullet shaped
(c) Tadpole like (d) Brick shaped

342. The protein-nucleic acid ratio of TMV is:
(a) 92.4 : 7.6 (b) 94.4 : 5.6
(c) 94.4 : 3.6 (d) 98.4 : 1.6

343. Which of the following is a mycoplasmic disease? (BAM 1991)
(a) Leaf curl of papaya (b) Black rust of wheat
(c) Red rot of sugar cane (d) Little leaf of brinjal

344. Point out the food poisoning and gas forming rod bacterium:
(a) *Clostridium* (b) *Salmonella*
(c) *Escherichia coli* (d) *Shigellia*

345. Typhus fever in human beings is caused by:
(a) Rickettsias (b) Spirochaetes
(c) L-form bacteria (d) Mycoplasma

346. The bacteria which lack flagella and move by gliding are included in? (BAM 1991)
(a) Spirochaetes (b) Rickettsia
(c) Myxobacteria (d) Eubacteria

347. A microbial mutant requiring growth factor in addition to a minimal medium is:
(a) Autotroph (b) Heterotroph
(c) Auxotroph (d) Syntroph

348. Transduction was first studied in:
(a) *Escherichia* (b) *Rhizobium*
(c) *Salmonella* (d) *Pneumococcus*

349. Infective part of virus was discovered by:
(a) Hershey and Chase (b) Morghan
(c) Stanley (d) Ivanowski

350. Which of the following viral diseases is found in domestic animals?
(a) Pneumonia (b) Jaundice
(c) Tuberculosis (d) None of these

351. Capsid of virus is made up of:
(a) Cellulose (b) Protein
(c) Mucoprotein (d) Starch

352. Which one of the following fixes CO_2 into carbohydrates? **(CET Chandigarh 1997)**
(a) *Rhizobium* (b) *Bacillus*
(c) *Nitrobacter* (d) *Rhodospirillum*

353. A cell wall material present only in bacteria and blue-green algae is: (BHU 1994, 97)
(a) Pectin (b) Cellulose
(c) Muramic acid (d) Chitin

354. Broad spectrum antibiotic is one which: (AMU 1995)
(a) Acts on bacteria and viruses
(b) Acts on a variety of pathogen micro-organisms
(c) Is effective in very small amounts
(d) Acts on both pathogens and hosts

355. Who among the following developed a vaccine for the first time? (DPMT 1997)
(a) Edward Jenner (b) Louis Pasteur
(c) John Salk (d) J. Lister

356. Which one of the following sets include the bacterial diseases? (AIIMS 1997; Pb. PMT 1997)
(a) Cholera, typhoid, mumps
(b) Tetanus, tuberculosis, measles
(c) Malaria, mumps, poliomyelitis
(d) Diphtheria, leprosy, plague

*357. If a certain person shows production of interferon in his body, the chances are that he has got an infection of: (CBSE 1997)
(a) Typhoid (b) Measles
(c) Malaria (d) Tetanus

358. The main difference between gram positive and gram negative bacteria resides in the composition of: (Manipal 1997; CBSE 2001)
(a) Cilia (b) Cell wall
(c) Nucleolus (d) Cytoplasm

359. The first indication of sexuality in bacteria was given by: (DPMT 1997)
(a) Leeuwenhoek (b) Pasteur
(c) Stanley (d) Lederberg and Tatum

360. Gram stain is: (CET Chandigarh 1997)
(a) A strain produced out of gram seed
(b) Trade mark
(c) A staining technique developed by the scientist Grams
(d) A chemical for differentation of bacteria

361. The following is an aerobic free living, non-photosynthetic, non-symbiotic, nitrogen-fixing soil bacterium: (BHU 1996)
(a) *Klebsiella* (b) *Rhizobium*
(c) *Clostridium* (d) *Azotobacter*

362. Antibiotics are mostly obtained from or maximum number or most of antibiotics have been obtained from: (AIIMS 1997)
(a) Bacteria (b) Viruses
(c) Angiosperms (d) Fungi

363. Which of the following is a prokaryote? (Pb. PMT 1997)
(a) *Spirogyra* (b) *Rhizopus*
(c) *Escherichia* (d) *Amoeba*

364. The term antibiotic was first used by: (DPMT 1997)
(a) Alexander Fleming (b) Selman Waksman
(c) J. Lister (d) L. Pasteur

365. Respiratory enzymes in bacteria are present in: (DPMT 1997)
(a) Mitochondria (b) Golgi complex
(c) Plasma membrane (d) E.R.

366. Bacteriophage is the name given to: (MPPMT 1996)
(a) A bacterium that infect a virus
(b) A virus which infects a bacterium
(c) A bacterium which infects the animal cell
(d) An organelle of the bacterium

367. Organisms which fix atmospheric nitrogen in the soil come under the category of: (Pb. PMT 1997)
(a) Soil fungi (b) Mosses
(c) Bacteria (d) Green algae

368. Tailed bacteriophages are: (CBSE 1995)
(a) Motile on surface of plant leaves
(b) Motile on surface of bacteria
(c) Non-motile
(d) Actively motile in water

369. Who was awarded Nobel Prize for passive immunity? (CBSE 1996)
(a) Emil Von Behring (b) Edward Jenner
(c) A. Fleming (d) Waksman

370. On the basis of host attacked, viruses are classified into: (MPPMT 1995)
(a) Two types (b) Three types
(c) Four types (d) Five types

371. Food poisoning is caused by: (CET Chandigarh 1997)
(a) *Bacillus megathrium* (b) *Salmonella typhi*
(c) *E. coli* (d) *Clostridium botulinum*

372. The genetic material in viruses is: (MPPMT 1995)
(a) Only RNA (b) Only DNA
(c) Either DNA or RNA (d) Protein and RNA

373. Plasmids found in the cells of bacteria are molecules of: (BHU 1994)
(a) DNA (b) RNA
(c) Proteins (d) DNA bound by histones

374. Mycoplasma are different from viruses in being sensitive to: (MPPMT 1995)
(a) Sugars (b) Tetracyclins
(c) Proteins (d) Amino acids

375. Pilli are the characteristic appendages of some: (BHU 1997)
(a) Algae (b) Viruses
(c) Bacteria (d) Mycoplasma

376. Which pair of disease is caused by viruses?
(a) Tetanus, cholera
(b) Whooping cough, AIDS
(c) Typhoid, sleeping sickness
(d) Measles, rabies

377. Food can be preserved by: (MPPMT 1997)
(a) Low temperature (b) High temperature
(c) Osmotic pressure (d) All of these

378. Which of the following statements is correct? (MPPMT 1996)
(a) Viruses are obligate parasites
(b) All fungi are pathogenic
(c) All algae are eukaryotic
(d) Bacteria are always harmful to mankind

379. Which one is a bacterial disease in plants?(Pb. PMT 1997)
(a) Late blight of potato (b) Citrus canker
(c) Rust of tea (d) Red rot of sugar cane

380. Which of the following is acellular? (CET Chandigarh 1997)
(a) Bacteria (b) Bacteriophage
(c) Diatom (d) Mycoplasma

381. The process conspicuously absent in viruses is: (Pb. PMT 1997)
(a) Mutation (b) Production of energy
(c) Replication (d) Protein synthesis

382. The gram stain used for differentiating the gram +ve and gram –ve germs of bacteria is: (CET Chandigarh 1997)
(a) Crystal violet and iodine
(b) Safranin and iodine
(c) Acetocarmine and iodine
(d) Safranin and gentian violet

383. The plant viruses that multiply within their insect vectors are called: (Pondicherry 1997)
(a) Persistent (b) Non-persistent
(c) Propagative (d) Circulative

384. The bacterial protoplasm is granular due to the presence of: (BHU 1997)
(a) Ribosomes (b) E.R.
(c) Lysosomes (d) None of these

385. A T-series bacteriophage can be recognised by: (Pondicherry 1996)
(a) Tadpole shape (b) Rounded shape
(c) Irregular shape (d) Rhomboidal shape

386. The site of respiration or oxidation of metabolites in bacteria is: (CBSE 1997; AMU 1997)
(a) Episome (b) Ribosome
(c) Mesosome (d) Microsome

*387. The bacteriophage contains an enzyme known as: (Manipal 1997)
(a) Dehydrogenase (b) Protease
(c) Urease (d) Lysozyme

388. Genes are packed into a bacterial chromosome by: (CBSE 1997)
(a) Histones (b) Basic proteins
(c) Acidic proteins (d) Actin

389. A free living aerobic soil bacterium capable of fixing nitrogen is: (CET Chandigarh 1997; CBSE 1997)
(a) *Azotobacter* (b) *Clostridium*
(c) *Rhizobium* (d) *Streptococcus*

390. Helical contractile sheath is found in: (AMU 1997)
(a) Fungi (b) Bacteria
(c) Virus (d) Bacteriophage

391. Which of the following organisms fix atmospheric nitrogen in free state (without association with a plant)? (AMU 1997; Manipal 1997)
(a) *Bacillus polymyxa* (b) *Nitrobacter*
(c) *Azospirillum* (d) *Rhizobium*

*392. Which is not true about antibiotics? (CBSE 1996; CET Chandigarh 1997)
(a) The term antibiotic was coined by Selman Waksman in 1942
(b) The first antibiotic was discovered by Alexander Fleming
(c) Each antibiotic is effective only against one particular kind of germ
(d) Some persons can be allergic to a particular antibiotic

393. Which one of the following statements about virus is correct? (CBSE 1997; CET Chandigarh 1997)
(a) Viruses possess their own metabolic system
(b) Viruses contain either DNA or RNA
(c) Viruses are facultative parasites
(d) Viruses are readily killed by antibiotics

394. Diphtheria is caused by: (CBSE 1997)
(a) Poisons released from dead bacterial cells into the host tissues
(b) Poisons released by living bacterial cells into the lost tissues
(c) Excessive immune response by the host body
(d) Poisons released by virus into the host tissues

395. Plasmids present in the bacterial cells are: (CBSE 1997)
(a) Circular double helical DNA molecules
(b) Circular double helical RNA molecules
(c) Linear double helical DNA molecules
(d) Linear double helical RNA molecules

396. Which of the following has the capacity to create resistance against infection? (Pb. PMT 1997)
(a) Immunoglobulins (b) Glycine
(c) Secondary proteins (d) Tyrosine

397. Chemoautotrophs do not require: (DPMT 1994)
(a) Sunlight (b) Ammonium compounds
(c) Hydrogen sulphide (d) Nitrites

398. RNA containing viruses are called: (AMU 1997)
(a) Deoxyvira (Deoxy virus)
(b) Ribovira (riboviruses)
(c) Ribobinala
(d) Riboculica

399. Cryptogram of influenza virus is: (AMU 1996)
(a) R/1 : 2-3/10 : S/E : V/A
(b) R/2 : 2/5 : E/E : */S
(c) R/1 : 2/5 : E/E : S/*
(d) R/1 : 1/8 : S/S : S/AP

400. Coliphage T_2-has: (AFMC 1997)
(a) Culex (b) ss-DNA
(c) ds-RNA (d) ds-DNA

401. Dengue is transmitted by: (AFMC 1997)
(a) Culex (b) Male anopheles
(c) Female anopheles (d) Tse-tse fly

402. Photosynthetic organisms which do not evolve O_2: (CPMT 1997)
(a) Green sulphur bacteria (b) Cyanobacteria
(c) *Rhizobium* (d) *Euglena*

403. Which is true about virus? (CPMT 1997)
(a) These lack cell organelle
(b) They have both DNA and RNA
(c) These can be facultative parasite also
(d) All of the above

404. Which one of the following is viral disease?
(a) Leaf curl of potato (b) Smut
(c) Wilt of arhar (d) None of these

405. Plasmid is: (CPMT 1997)
(a) Extrachromosomal gene present in bacteria
(b) Extrachromosomal gene present in cyanobacteria
(c) Both (a) and (b)
(d) None of the above

406. RNA particles without protein sheath are: (CPMT 1997)
(a) Viroid (b) Virus
(c) Mycoplasma (d) Rickettse

407. Genetic transfer through viruses in bacteria is called: (BHU 1997)
(a) Sexduction (b) Transduction
(c) Configuration (d) Transformation

408. Penicillin checks the bacterial growth by: (CPMT 1998)
(a) Inhibiting cell wall growth
(b) Inhibiting protein synthesis
(c) Inhibiting RNA synthesis
(d) Destroying cell membrane

409. Typhoid fever is caused by: (CBSE 1998)
(a) *Escherichia* (b) *Salmonella*
(c) *Shigella* (d) *Giardia*

410. A bacterium divides every 35 minutes. If a culture containing 10^5 cells per mL is grown for 175 minutes, what will be the cell concentration per mL after 175 minutes? (CBSE 1998)
(a) 32×10^5 cells (b) 5×10^5 cells
(c) 35×10^5 cells (d) 175×10^5 cells

411. Transfer of genetic information from one bacterium to another in the transduction process is through: (CBSE 1998)
(a) Physical contact between donor and recipient strains
(b) Conjugation
(c) Bacteriophages released from the donor bacterial strain
(d) Another bacterium

412. The DNA of *E. coli* is: (CBSE 1998)
(a) Single stranded and circular
(b) Single stranded and linear
(c) Double stranded and linear
(d) Double stranded and circular

413. A few organisms are known to grow and multiply at temperatures of 100–105°C. They belong to:
(a) Thermophillic sub-aerial fungi
(b) Marine archaebacteria
(c) Thermophillic sulphur bacteria
(d) Hot-spring blue-green algae

414. Human Immunodeficiency Virus (HIV) has a protein coat and a genetic material which is: (CBSE 1998; AIIMS 2001)
(a) Double stranded RNA (b) Single stranded DNA
(c) Double stranded DNA (d) Single stranded RNA

415. Botulism caused by *Clostridium botulinum* affects the: (CBSE 1998)
(a) Intestine (b) Lymph glands
(c) Neuromuscular junction (d) Spleen

416. Most bacteria causing plant diseases are best described as: (CBSE 1999)
(a) Gram +ve spore forming cocci
(b) Gram –ve non-spore forming rods
(c) Gram –ve spore forming cocci
(d) Gram +ve non-spore forming rods

417. The cell in the human body invaded by HIV or human immunodeficiency virus is: (CBSE 1999)
(a) T-helper cell (b) B-cell
(c) Erythrocyte (d) Macrophage

418. Tea leaves are cured and flavoured by: (CPMT 1999)
(a) *Clostridium botulinum* (b) *Clostridium perfringens*
(c) *Bacillus megatherium* (d) None of these

*419. F-gene present in bacteria is meant for: (BHU 1999)
(a) Sexuality (b) Locomotion
(c) Nutrition (d) None of these

420. Number of chromosomes present in bacteria is: (AIIMS 1999)
(a) 1 (b) 2
(c) 4 (d) Many

421. Sub-unit of coat of virus is: (AIIMS 1999)
(a) Nucleosome (b) Capsomere
(c) Nucleotide (d) None of these

422. Potato leaf roll disease is caused by: (MPPMT 1999)
(a) Mycoplasma (b) Virus
(c) Microspores (d) Bacterium

423. A plasmid: (MPPMT 1999)
(a) Lives together with chromosome
(b) Shows dependent assortment
(c) Can replicate independently
(d) Cannot replicate

424. Bacterial cells can be stained with: (MPPMT 1999)
(a) Mercuric chloride (b) Crystal violet
(c) Crystal violet and iodine (d) Safranin

425. Mucopeptide in cell wall is more in: (MPPMT 1999)
(a) Gram +ve bacteria (b) Gram –ve bacteria
(c) Cyanobacteria (d) Bacteriophage

426. Diphtheria is caused by: (MPPMT 1999)
(a) Viruses (b) Eukaryotes
(c) Mycoplasma (d) Bacteria

427. Which of the following statements is true for mycoplasma? (MPPMT 1999)
(a) Presence of cell wall (b) Presence of nucleus
(c) Absence of cell wall (d) Definite shape

428. Bacteria obtaining energy from oxidation of inorganic substances are called: (MPPMT 1999)
(a) Chemolithotrophs (b) Photolithotrophs
(c) Photoorganotrophs (d) Chemoorganotrophs

429. Plant viruses have: (MPPMT 1999)
(a) DNA only (b) RNA only
(c) Both DNA and RNA (d) Coiled nucleolus

*430. Enzymes are absent in: (CBSE 2000)
(a) Virus (b) Fungi
(c) Algae (d) Bacteria

431. Viruses are living because they: (CBSE 2000)
(a) Can reproduce (in host) (b) Can respire
(c) Can die (d) Can cause disease

432. Interferons are: (CBSE 2000)
(a) Antiviral proteins (b) Complex proteins
(c) Antibacterial proteins (d) Anticancer proteins

433. Which is not found in bacteria? (CPMT 2000)
(a) Mesosome (b) Capsule
(c) Nucleus (d) Flagella

434. Viruses cannot be synthesized artificially because:
(a) They have closed system
(b) They do not have their own metabolism
(c) They do not show sexual reproduction
(d) All of the above

435. TMV capsid has capsomeres numbering: (CET Karnataka 2000)
(a) 2310 (b) 3120
(c) 1230 (d) 2130

436. Who classified bacteria under Schizomycetes? (MPPMT 2000)
(a) Nageli (b) Linnaeus
(c) Leeuwenhoek (d) Sadasivan

437. The disease 'Pneumonia' is caused by: (MPPMT 2000)
(a) Virus (b) Cyanobacteria
(c) Bacteria (d) Cold

438. Bacteria reproduce sexually by: (MPPMT 2000)
(a) Endospores (b) Transformation
(c) Conidia (d) Exospores

439. The viral capsid is made up of: (MPPMT 2000)
(a) Nucleic acids (b) Proteins
(c) Lipids (d) Carbohydrates

440. Mycoplasma are not sensitive to: (MPPMT 2000)
(a) Streptomycin (b) Penicillin
(c) Erythromycin (d) Neomycin

*441. Sexual reproduction is absent in: (MPPMT 2000)
(a) Cyanobacteria (b) Bacteria
(c) Eukaryote (d) All of these

442. Cell wall of bacteria is composed of: (CET Karnataka 2001)
(a) Chitin (b) Murein
(c) Suberin (d) Cellulose

*443. Antibiotics are given during: (Manipal 2001)
(a) Pneumonia (b) Measles
(c) Mumps (d) AIDS

*444. Which of the following bacteria is found in faeces of 3-4% human population? (Manipal 2001)
(a) *Escherichia* (b) *Entamoeba*
(c) *Clostridium* (d) *Lactobacillus*

445. Cauliflower mosaic virus contains: (CBSE 2001)
(a) ss-RNA (b) ds-RNA
(c) ds-DNA (d) ss-DNA

446. What is true for Archaebacteria? (CBSE 2001)
(a) All halophils (b) All photosynthetics
(c) All fossils (d) Oldest living beings

447. *Agrobacterium tumefaciens* causes: (Uttaranchal PMT 2001)
(a) Crown gall disease (b) Syphilis
(c) Plague (d) Poisoning

448. Bacterial cell wall is made up of peptidoglycan which has: (Uttaranchal PMT 2001)
(a) Peptide chain linked with NAM and NAG
(b) Peptide chain linked with lipid
(c) Only peptide chain
(d) Only lipid and amino acid chains

449. When in a bacterial cell, flagella are present singly at both the ends, then it is called: (CPMT 2001)
(a) Lophotrichous (b) Amphitrichous
(c) Monotrichous (d) Peritrichous

450. In bacteria, site of respiration is: (AFMC 2001; CPMT 2002)
(a) Cytoplasm (b) Mesosome
(c) Episome (d) Plasmid

451. To find *E. coli* cultures, you should look for: (AFMC 2001)
(a) Human placenta (b) Human intestine
(c) Rabbit's saliva (d) Human hair

452. Which of the following is a bacterial disease? (AFMC 2001)
(a) AIDS (b) Leprosy
(c) Ascariasis (d) Polio

453. Extrachromosomal genetic material is found in bacteria in: (MPPMT 2001)
(a) Plasmid (b) Microsomes
(c) Ribosomes (d) None of these

454. Pilli in bacteria represent: (BHU 2001)
(a) Small flagella
(b) Special bacterial cilia
(c) Extrachromosomal genetic element
(d) Cell membrane outgrowth of donor cells

455. *Streptomyces fradiae* produces: (MPPMT 2001)
(a) Erythromycin (b) Neomycin
(c) Terramycin (d) Aureomycin

456. Sewage water can be purified for recycling with the action of: [BCECE (P.T. Exam.) 2001]
(a) Aquatic plants (b) Penicillin
(c) Micro-organisms (d) Fishes

457. Which of the following species is the smallest bacteria? (CPMT 2002)
(a) *Dialister* (b) *Spirillum*
(c) *Caryophanon* (d) *Beggiatoa*

458. Exotoxins released by micro-organisms cause: (CPMT 2002)
(a) Botulism (b) Diphtheria
(c) Tetanus (d) All of these

459. Which of the following is an ammonifying bacterium? (CPMT 2002)
(a) *Clostridium* (b) *Azotobacter*
(c) *Nitrosococcus* (d) *Bacillus ramosus*

460. Mycoplasma is: (JIPMER 2002)
(a) Eukaryotic and unicellular
(b) Eukaryotic and multicellular
(c) Prokaryotic and unicellular
(d) Prokaryotic and multicellular

*461. The genome of transducting phages is: (JIPMER 2002)
(a) Single stranded RNA (b) Double stranded RNA
(c) Single stranded DNA (d) Double stranded DNA

462. The process which cannot take place in absence of viruses is: (CET Karnataka 2002)
(a) Transduction (b) Translocation
(c) Conjugation (d) Transformation

463. HIV decreases natural immunity of the body by: (CET Karnataka 2002)
(a) Attacking B-lymphocytes
(b) Attacking T-lymphocytes

(c) Destroying erythrocytes
(d) Destroying antibodies

464. Organisms found in extreme temperatures are: (DPMT 2001)
(a) Cyanobacteria (b) Archaebacteria
(c) Fungi (d) Eubacteria

465. The correct sequence of phases in the growth curve of bacteria is: (CBSE 2002)
(a) Stationary, lag, log and decline
[✓ (b) Lag, log, stationary and decline]
(c) Log, lag, stationary and decline
(d) Log, lag, decline and stationary

466. The semilog of per minute growing bacteria is plotted against time. What will be the shape of the graph? (CBSE 2002)
(a) Sigmoid (b) Hyperbole
(c) Ascending straight line (d) Descending straight line

467. Transformation experiment was conducted on: (CBSE 2002)
(a) *Diplococcus pneumoniae* (b) *E. coli*
(c) *Salmonella typhi* (d) All of these

468. AIDS was first discovered in: (St. Jones 2002)
(a) 1984 in America (b) 1984 in France
(c) 1981 in America (d) 1981 in Asia

*469. Which one of the following organisms may respire in the absence of oxygen? (MPPMT 2002)
(a) *Azotobacter* (b) *Clostridium*
(c) *Rhizobium* (d) *Lactobacillus*

470. Which disease is caused by virus? (MPPMT 2002)
(a) Diphtheria (b) Polio
(c) Tuberculosis (d) Typhoid

471. Which type of organism are PPLO? (MPPMT 2002)
(a) Virus (b) Viroid
(c) Mycoplasma-like (d) Bacteria

472. Which of the following is a disease causing bacterium in human beings? (MPPMT 2002)
(a) *Marmor vigratum* (b) *Xanthomonas citri*
(c) TMV (d) *Vibrio cholerae*

473. Which of the following is a peritrichous bacterium? (MPPMT 2002)
(a) *Vibrio* (b) *Spirillum*
(c) *Bacillus typhosus* (d) *Pseudomonas*

474. Which is the cause of anthrax disease? (MPPMT 2002)
(a) Virus (b) Bacteria
(c) Mycoplasma (d) Algae

475. Which of the following is a bacteriophage? (MPPMT 2002)
(a) Virus infecting bacteria (b) Vibrio bacteria
(c) Bacteria infecting virus (d) Cyanobacteria

476. Retroviruses have: (DPMT 2001)
(a) Only RNA as genetic material
(b) Only DNA as genetic material
(c) DNA and RNA as genetic material
(d) Genes on nucleoprotein complexes as genetic material

477. The viruses with nucleic acid but without protein coat are known as: (EAMCET 2002)
(a) Viroids (b) Virions
(c) Capsomeres (d) Prions

478. *Xanthomonas citri* possess: (EAMCET 2002)
(a) Tuft of flagella (b) Bipolar flagella
(c) Single polar flagellum (d) No flagella

479. Largest and most diverse group of photosynthetic bacteria is:
(a) Green sulphur bacteria (b) Purple sulphur bacteria
(c) Cyanobacteria (d) Archaebacteria

480. Phycobilisomes, the structures containing phycobilin pigments, are present in:
(a) Eubacteria (b) Cyanobacteria
(c) Archaebacteria (d) None of these

481. Most of the cyanobacteria appear blue-green in colour because of:
(a) Phycoerythrin (b) Phycocyanin
(c) Chlorophyll-a (d) None of these

482. Cyanobacteria have typical:
(a) Gram-positive type cell wall
(b) Gram-negative type cell wall
(c) Both (a) and (b)
(d) None of the above

483. Cyanobacteria capable of forming water blooms are:
(a) *Anacystis* (b) *Anabaena*
(c) Both (a) and (b) (d) None of these

484. Cyanobacteria are symbionts with:
(a) Protozoa (b) Liverworts and mosses
(c) Gymnosperms (d) All of these

485. Which of the following is present only in the inert extracellular stage of the life cycle of virus? (CPMT 2002)
(a) Capsid (b) Proteins
(c) Ribosomes (d) All of these

486. Type of genetic material present in bacteria is: (BHU 2002)
(a) DNA bound with protein
(b) DNA not bound with protein
(c) RNA bound with protein
(d) RNA not bound with protein

487. The outermost limiting layer of mycoplasma is made up of: (Orissa JEE 2002)
(a) Cell wall (b) Cell membrane
(c) Mucilaginous sheath (d) Slime-layer

488. Prophage refers to: (Orissa JEE 2002)
(a) Viral genome outside the host cell
(b) Viral genome incorporates and integrates with bacterial genome
(c) Viral genome inoculated to bacterial genome
(d) Freshly synthesized viral genome within the host cell

489. Bacteria do not have: (CPMT 2003; Kerala PMT 2003)
(a) Ribosome
(b) Protein synthesizing apparatus
(c) Mitochondria
(d) Cell wall

490. Pigment present in cyanobacteria is: (CPMT 2003)
(a) r-phycocyanin (b) r-phycoerythrin
(c) c-phycocyanin (d) Anthocyanin

491. Antibodies in our body are produced by: (BHU 2003)
(a) B-lymphocytes (b) T-lymphocytes
(c) Monocytes (d) RBC's

492. By all of the following ways bacteria become resistant to antibiotic except: (Orissa JEE 2003)
(a) Making enzymes that inactivate the drug
(b) Becoming impermeable to the drug
(c) Modifying the target of the drug
(d) Moving away from the drug

493. Heating food to 100°C will prevent all but the following diseases: (Orissa JEE 2003)
(a) *Salmonella* infection (b) Cholera
(c) Botulism (d) Hepatitis-B

494. Genetic material of Human Immuno-deficiency Virus is: (Orissa JEE 2003)
(a) Protein (b) RNA
(c) Double stranded DNA (d) Single stranded DNA

495. Interferons are produced in response to: (DPMT 2003)
(a) Virus (b) Bacteria
(c) Helminthes (d) Malarial parasites

496. Single stranded nucleic acid is found in: (DPMT 2003)
(a) *E. coli* (b) $\phi \times 174$
(c) λ (d) T_4

497. Chl.-a is absent in which of the following photosynthetic organisms? (DPMT 2003)
(a) Cyanobacteria (b) Red algae
(c) Brown algae (d) Bacteria

498. The gram-negative bacteria detect and respond to chemicals in their surroundings by: (Kerala PMT 2003)
(a) Lipopolysaccharide (b) Muramic acid
(c) Porins (d) Volutin granules
(e) Mesosomes

499. The amino acid found only in bacteria and blue-green algae is: (Kerala PMT 2003)
(a) Methionine (b) Muramic acid
(c) Diamino-palmic acid (d) Glutamic acid
(e) Asparagines

500. Which of the following may manufacture the food material? (B.V. Pune 2003)
(a) Nostoc (b) Virus
(c) Mycoplasma (d) All of these

501. The virus which was first isolated: (B.V. Pune 2003)
(a) Polio virus (b) Influenza virus
(c) Tobacco mosaic virus (d) Cyanophage

502. Tobacco mosaic virus is a tubular filament of size: (CBSE 2003)
(a) 300 × 5 nm (b) 300 × 20 nm
(c) 700 × 30 nm (d) 300 × 10 nm

503. Which of the following statements about viruses is correct? (CBSE 2003)
(a) Viruses are obligate parasites
(b) All viruses contain both RNA and DNA
(c) Nucleic acid of viruses is known as capsid
(d) Viruses possess their own metabolic system

504. Chromosomes in a bacterial cell can be 1–3 in number and are: (CBSE 2003)
(a) Never circular (b) Always linear
(c) Always circular (d) Always elliptical

505. The nuclear material in bacterial cell is called: (PMET Punjab 2003)
(a) Cellulose (b) Nucleoid
(c) Mucopeptide (d) Mesosome

ANSWERS

1—d	2—d	3—c	4—d	5—b	6—d	7—c	8—c	9—d	10—d	11—d	12—b
13—c	14—c	15—c	16—b	17—d	18—d	19—b	20—d	21—b	22—c	23—c	24—c
25—b	26—d	27—c	28—c	29—c	30—d	31—c	32—b	33—b	34—b	35—d	36—d
37—c	38—d	39—d	40—b	41—a	42—d	43—d	44—b	45—c	46—b	47—b	48—c
49—b	50—c	51—c	52—c	53—b	54—c	55—b	56—b	57—d	58—b	59—d	60—c
61—c	62—d	63—b	64—b	65—a	66—b	67—d	68—d	69—c	70—d	71—c	72—b
73—b	74—c	75—a	76—c	77—c	78—b	79—b	80—c	81—b	82—c	83—d	84—a
85—b	86—a	87—d	88—c	89—a	90—c	91—d	92—a	93—a	94—c	95—c	96—d
97—b	98—b	99—a	100—a	101—b	102—b	103—c	104—a	105—b	106—b	107—a	108—d
109—b	110—d	111—c	112—a	113—b	114—c	115—c	116—a	117—d	118—b	119—d	120—a
121—d	122—c	123—d	124—a	125—c	126—b	127—a	128—d	129—d	130—c	131—a	132—c
133—d	134—a	135—a	136—a	137—b	138—c	139—c	140—b	141—b	142—b	143—a	144—b
145—b	146—b	147—a	148—b	149—c	150—d	151—c	152—c	153—b	154—c	155—c	156—b
157—c	158—a	159—c	160—c	161—b	162—c	163—c	164—c	165—c	166—a	167—b	168—a
169—b	170—b	171—c	172—c	173—b	174—a	175—a	176—d	177—a	178—c	179—a	180—b
181—c	182—c	183—c	184—c	185—d	186—a	187—c	188—a	189—c	190—c	191—a	192—c
193—a	194—b	195—d	196—d	197—a	198—b	199—d	200—b	201—b	202—c	203—b	204—b
205—b	206—d	207—c	208—c	209—a	210—a	211—d	212—d	213—c	214—c	215—d	216—a
217—d	218—a	219—c	220—d	221—d	222—c	223—c	224—c	225—d	226—b	227—a	228—d
229—b	230—b	231—b	232—b	233—a	234—c	235—d	236—b	237—c	238—a	239—c	240—a

241—c	242—a	243—d	244—d	245—b	246—b	247—c	248—b	249—c	250—b	251—b	252—b
253—c	254—b	255—c	256—c	257—a	258—d	259—a	260—a	261—c	262—b	263—c	264—c
265—b	266—b	267—c	268—b	269—a	270—a	271—b	272—d	273—d	274—b	275—d	276—a
277—b	278—d	279—a	280—a	281—d	282—b	283—c	284—a	285—c	286—b	287—c	288—c
289—a	290—c	291—c	292—b	293—d	294—d	295—c	296—b	297—b	298—c	299—a	300—c
301—a	302—c	303—c	304—c	305—d	306—c	307—d	308—a	309—a	310—b	311—d	312—c
313—a	314—b	315—a	316—a	317—a	318—a	319—b	320—d	321—b	322—a	323—a	324—c
325—b	326—b	327—a	328—a	329—b	330—a	331—c	332—c	333—d	334—b	335—b	336—c
337—c	338—c	339—b	340—b	341—b	342—b	343—d	344—a	345—a	346—c	347—c	348—c
349—a	350—a	351—b	352—d	353—c	354—b	355—a	356—d	357—b	358—b	359—d	360—d
361—d	362—a	363—c	364—b	365—c	366—b	367—c	368—c	369—a	370—b	371—d	372—c
373—a	374—b	375—c	376—d	377—a	378—a	379—b	380—b	381—b	382—a	383—c	384—a
385—a	386—c	387—d	388—c	389—a	390—d	391—a	392—c	393—b	394—b	395—a	396—a
397—a	398—b	399—a	400—d	401—a	402—a	403—a	404—a	405—a	406—a	407—b	408—a
409—b	410—a	411—c	412—d	413—c	414—d	415—c	416—b	417—a	418—c	419—a	420—a
421—b	422—b	423—c	424—c	425—a	426—d	427—c	428—a	429—b	430—a	431—a	432—a
433—c	434—b	435—d	436—a	437—c	438—b	439—b	440—b	441—a	442—b	443—a	444—a
445—c	446—d	447—a	448—a	449—b	450—b	451—b	452—b	453—a	454—d	455—b	456—c
457—a	458—d	459—d	460—c	461—a	462—a	463—b	464—b	465—b	466—c	467—a	468—c
469—b	470—b	471—c	472—d	473—c	474—b	475—a	476—a	477—a	478—c	479—c	480—b
481—b	482—b	483—c	484—d	485—a	486—b	487—b	488—b	489—c	490—c	491—a	492—d
493—d	494—b	495—a	496—b	497—d	498—c	499—b	500—a	501—c	502—b	503—a	504—c
505—b											

EXPLANATION OF SELECTED QUESTIONS (*)

25. As F-factor can remain independently as well as in integrated form with main bacterial genome, so it is an episome.
37. Main source of antibiotics are filamentous bacteria called actinomycetes, *e.g.*, *Streptomyces*.
72. PPLO or mycoplasma are smallest aerobic organisms with prokaryotic cell organization.
90. Due to addition of salts, osmotic concentration of pickles is increased as a result of which exosmosis occurs out of bacterial cells and thus bacteria are plasmolysed and killed.
98. The cell walls of Gram –ve bacteria are multilayered (lipopolysaccharides, phospholipids, lipoproteins and peptidoglycans) and hence more complex.
108. Conjugation occurs between F^+ (donor cell) and F^- (recipient cell) bacterial cells and hence F-factor (episome) is responsible for sex determination.
118. Rickettsiae are distinct organisms which cause Rocky mountain spotted fever and typhus fever (discovered by Howard Taylor Ricketts). Initially these were set apart from bacteria but in recent times, these have been included in bacteria (in recent Bergey's Manual).
140. Interferons are antiviral agents controlling viral infections (cancer with which rous sarcoma virus is associated).
149. Photosynthetic bacteria have chromatophores and have only PS-I with P-890 as reaction centre.
158. Enteric bacterial food poisoning is caused by *E. coli* or *Salmonella typhineurium.*
180. Chemosynthetic bacteria use chemical energy (instead of light energy) in formation of food.
183. *Haemophilus influenzae* bacteria cause Heamophilus meningitis.
258. Apical meristems are not infected by viruses.
315. Nitrogen fixing (Nif) genes are present in *Rhizobium.*
357. Interferons are produced in cells after infection of virus and hence found in body of person infected with measles (a viral disease).
387. Lysozyme is secreted by tail fibres of bacteriophage.
392. Antibiotics may be narrow-spectrum or broad-spectrum.
419. F-gene or factor (episome) in bacteria is meant for sexuality.
430. Viruses lack enzymes or enzyme system.
441. Sexual reproduction is totally absent in cyanobacteria (blue-green algae).
443. Antibiotics generally are bactericides (bacteria killers).
444. *E. coli* lives as symbiont in human intestine and it comes out with faeces of large number of people. It is indicator of sewage pollution in water.
461. The genome of transducting phage (*e.g.*, Retroviruses) is single stranded RNA.
469. The members of genus *Clostridium* are anaerobic and form heat resistant endospores.

10

Algae

- General characters
- Famous algologists
- Habitat of Algae
- Range of vegetative structure in Algae
- Variation in chromosomes in Algae
- Reproduction in Algae
- Classification of Algae
- Economic importance of Algae
- Life cycle of *Chlamydomonas*
- Life cycle of *Ulothrix*
- Life cycle of *Spirogyra*

Study of algae is known as **Phycology or Algology.**

The term 'Phycology' is derived from two Greek words: *Phykos,* Greek name of an alga + *logos*, study or discourse.

- Term 'Algae' was given by **Linnaeus** (derived from a Latin word Alga—meaning sea weeds).

Algae include the **chlorophyllous non-vascular** plants with thallose plant body, *i.e.*, with no differentiation of root, stem and leaves.

Algae are from unicellular microscopic forms to large multicellular forms.

The characteristic features of algae are as follows:

1. These are chlorophyll bearing plants with thallose plant body.
2. They have little differentiation of true tissue.
3. Even the complex forms of algae lack vascular tissue (xylem, phloem, etc.).
4. Sex organs are **unicellular and non-jacketed** and when muticellular, each cell is fertile.
5. There is **no embryo** formation after fertilization in life cycle.
6. Most of the algae are **aquatic.**
7. When there are two phases, *i.e.*, gametophytic and sporophytic phases in life cycle, they are independent of each other.
8. Under favourable conditions, the plant body reproduces asexually by **means of mitospores** (formed after mitosis).

FAMOUS ALGOLOGISTS OR PHYCOLOGISTS

- **Dr. F.E. Fritsch:** Famous international algologist and he is known as **Father of algae.**

Famous algologists of India

- Ghose (1919) was the pioneer Indian worker who studied algae.
- **Prof. M.O.P. Iyenger:** He was the student of Dr. F.E. Fritsch, started study of algae in 1920 in **Madras University.** He is known as **Father of Modern Algology in India.** His important contribution is discovery of **terrestrial alga** called *Fritschiella tuberosa.*

  In Madras (Chennai) besides Prof. Iyenger, other famous algologists are **Ramanathan, Balakrishnan** and **Desikachary.**
- In B.H.U., **Prof. Y. Bhardwaj** (student of Fritsch) and **Prof. R.N. Singh:** His important work is reclamation of **saline usher land by growing blue-green algae,** also role of blue-green algae in nitrogen economy of Indian agriculture. (Although, **P.K. De** was the pioneer in establishing the N_2-fixing ability of blue-green algae.)
- **Prof. H.D. Kumar** worked on algae physiology. He also studied genetic recombination in Blue-green algae or Cyanophyceae or Myxophyceae or Cyanobacteria.

HABITAT OR OCCURRENCE OF ALGAE

Algae are universal in occurrence and found in variety of habitats as in fresh water, marine water, hot springs, snow, etc.

1. **Algae found in mud:** *e.g.*, *Chara* (stone wort).

2. **Algae found at the banks of lakes and ponds:** *e.g.*, *Rivularia* and *Spirogyra.*

3. **Thermophytic algae:** Found in high temp., *i.e.*, 70–80°C or in hot springs, *e.g.*, *Oscillatoria brewis, Heteroharmogonium, Haplosiphon, Synechoccus elongatus*, etc.

4. **Cryophytic algae:** Algae which are found in very low temp., *i.e.*, in snow and these algae provide different colours to the snow, *e.g.*,

(a) **Red snow:** Caused by *Chlamydomonas nivalis* and *Haematococcus nivalis.*

- **Due to haematochrome** pigment in thick walls of their **hypnospores.**

(b) **Green snow:** Caused by *Chlamydomonas yellowstonensis.*

(c) **Black snow:** Caused by *Scotiella nivalis* and *Raphidonema.*

5. **Epiphytic algae:** Algae living on other plants including algae. *e.g., Bulbochaete, Oedogonium* and *Microspora,* living upon *Cladophora, Rhizoclonium* and *Vaucheria* respectively.

6. **Epizoic algae:** Algae found on other animals, *e.g., Cladophora* on snail, *Protoderma* on back of tortoise and *Stigeocolonium* on gills of fish.

7. **Endozoic algae:** Which live inside animals, *e.g., Zoochlorella* found in gastrodermal tract of *Hydra.*

8. **Parasitic algae:** *Cephaleuros virescens* (green alga) causes **red rust of tea,** coffee and *Magnolia.*

- *Phyllobium sphagnicolum* is parasite on *Sphagnum* (moss).
- Some species of *Oscillatoria* are mild parasites in the intestine of animals including man.
- *Harveyella* is parasitic red alga which lives as parasite on other photosynthetic red algae.

9. **Terrestrial algae:** *Fritschiella tuberosa, Botrydium* and *Vaucheria* are present on soil surface and these are also known as **sapophytic algae.**

10. **Cryptophytic algae:** *Nostoc* species are present below soil surface and are called **cryptophytic.**

11. **Marine algae:** Brown algae and red algae are marine, *e.g., Fucus, Laminaria, Sargassum, Macrocystis* (largest alga in nature), *Polysiphonia,* etc.

- Brown algae (Phaeophyceae) are commonly known as **sea weeds or kelps.**

12. **Halophytic algae:** In high salt concentration, *e.g., Chlamydomonas ehrenbergii.*

13. **Symbiotic algae:** *e.g.,* In lichens, some members of blue-green algae and green algae live in symbiotic association with fungal partner.

- Some blue-green algae like *Nostoc* and *Anabaena* are found symbiotically in thallus of *Anthoceros* (Horn wort), *Azolla* and also in coralloid roots of *Cycas.*
- Some species of *Cladophora* live in symbiotic association in a sponge *Eplydatea.*

○ **Cyanallae:** Blue-green algae living inside protozoans are called **cyanallae.**

RANGE OF VEGETATIVE STRUCTURE IN ALGAE

Algae are unicellular or multicellular.

Structure algae

(A) Unicellular

These are of following two types:

(a) **Motile:** In these algae movement takes place by flagella, *e.g., Chlamydomonas.* Variation is found in number and type of flagella.

(1) In **Chlorophyceae** flagella are equal, number may be two or multiple of two.

(2) In **Dinophyceae** and **Xanthophyceae,** unequal flagella; in former they emerge in different planes and in latter in the same plane.

(3) In **Euglenophyceae,** single flagellum at the anterior end.

(b) **Non-Motile:** These are coccoidal algae, flagella are absent, *e.g., Chlorella,* diatoms.

○ Simplest non-motile forms are found in Cyanophyceae (prokaryotic), *e.g., Chroococcus.*

(B) Multicellular

These are of following types:

(a) **Colonial:** These are motile algae, having definite number of cells, *e.g., Volvox.* On the basis of morphology, these are divided into four types:

(1) **Coenobial:** A colony with a definite shape, size and arrangement of cells is known as **coenobium,** may be motile or non-motile, *e.g., Pandorina, Eudorina, Volvox* (motile) and *Hydrodictyon* (non-motile).

(2) **Palmelloid:** Indefinite number of cells, shape and size surrounded by a viscous mucilaginous substance, *e.g., Tetraspora, Aphanotheca, Chlamydomonas* (temporary phase).

(3) **Dendroid:** Cells of these forms produce mucilaginous substance and are folded like a branch, *e.g., Chrysodendron.*

(4) **Rhizopodial:** Cells are united through rhizopodia, *e.g., Chrysidiastrum.*

(b) **Filamentous:** These are of following types:

(1) **Unbranched filaments:** Such filaments may be:

(i) **Free floating:** *e.g., Spirogyra.*

(ii) **Attached to some substratum:** *e.g., Ulothrix, Oedogonium.*

(iii) **Form a colony:** *e.g., Nostoc, Oscillatoria.*

(2) **Branched filaments:** Simple branched filaments, *e.g., Scytonema, Cladophora.*

(i) **Heterotrichous:** Thallus differentiated into prostrate and erect systems, *e.g., Fritschiella, Ectocarpus, Draparnaldiopsis, Coleochaete, Stigeoclonium,* etc.

(ii) **Pseudoparenchymatous:** These algae are characterised by uniaxial filament, *e.g., Polysiphonia, Batrachospermum* and multiaxial filament, *e.g., Nemalion.*

(iii) **Siphonaceous forms:** These algae consist of multinucleate tube-like cells having no septa, *e.g., Vaucheria, Botrydium.*

(iv) **Parenchymatous forms:** In these algae, cell division takes place on different sides with the result that they become parenchymatous, having various shapes such as flat—*Ulva,* tubular—*Scytosiphon* or complex—*Sargassum.* The growth in such forms may be **intercalary,** *e.g., Laminaria,* **trichothallic,** *e.g., Porphyra* or **apical,** *e.g., Fucus.*

VARIATION IN SHAPE, SIZE AND NUMBER OF CHROMOSOMES IN ALGAE

There is a great variation in the morphology of chromosomes:

(i) Chromosomes are small and spherical in desmids (*Cosmarium*).

(ii) Elongated and thread-like in *Oedogonium*.

(iii) Chromosomes may have a localized (median or subterminal) or diffused centromere.

(iv) Size of chromosomes varies from 0.25 μm or less, *e.g.*, Ulotrichales to more than 12 μm, *e.g.*, Oedogoniales and Charales.

(v) Number of chromosomes also show much variation. The lowest number n = 2 in *Porphyra linearis* and the highest n = 592 in *Netrium digitalis*.

REPRODUCTION

Reproduction in algae takes place by the following methods:

(A) Vegetative reproduction
(B) Asexual reproduction
(C) Sexual reproduction

(A) Vegetative reproduction

It is the most common method of reproduction. It takes place by the following means:

(i) **Fragmentation:** Thallus breaks into small fragments and each part gives rise to a new plant, *e.g.*, *Ulothrix*, *Spirogyra* and *Zygnema*.

(ii) **Cell division or fission:** Simplest method of propagation commonly found in unicellular algae, desmids and diatoms. Unicellular algal cell divides mitotically to form two daughter cells, each grows into independent organism.

(iii) **Hormogonia:** It is a characteristic method of reproduction in blue-green algae. The trichome breaks into motile segments called hormogonia, *e.g.*, *Nostoc*, *Oscillatoria*, etc.

(iv) **Tubers:** On the rhizoids and lower nodes of *Chara*, tubers are formed, which after detaching produce independent plants, *e.g.*, *Cladophora*.

(v) **Budding:** In some algae, bud-like structures are formed, they eventually get separated from the parent plant by septa and form new plants, *e.g.*, *Protosiphon*.

(B) Asexual reproduction

Generally takes place by the following methods:

(i) **By zoospores:** Under favourable conditions biciliated (*e.g.*, *Ulothrix*), tetraciliated (*e.g.*, *Ulothrix*) or multiciliated (*e.g.*, *Oedogonium*) zoospores are formed and on bursting of mother cell (zoosporangium) gives rise to new plants.

(ii) **By aplanospores:** In this type, the protoplasm gets separated from the cell wall to form, **thin-walled** non-ciliated aplanospores and each aplanospore gives rise to a new plant, *e.g.*, *Chlorella*, *Ulothrix*, *Microspora*.

(iii) **By hypnospores:** Protoplasm of the cell separates from the cell wall and collects in the centre to form non-motile and **thick-walled**, hypnospore, which under favourable conditions gives rise to a new plant, *e.g.*, *Vaucheria*, *Chlamydomonas nivalis* (haematochrome pigment in the wall).

(iv) **By tetraspores:** Diploid plants of some algae form tetraspores usually by meiosis and give rise to a haploid plants, *e.g.*, *Polysiphonia*.

(v) **By akinetes:** In this process, **entire cell becomes thick** to form akinete and in favourable conditions each akinete develops into a new plant, *e.g.*, *Cladophora*.

(vi) **Palmella stage:** In dry conditions, zoospores or aplanospores get surrounded by mucilaginous sheath. The divisions continue and they take the shape of a colony. This is known as palmella stage. Under favourable conditions each zoospore gives rise to a new plant, *e.g.*, *Chlamydomonas*.

(vii) **By autospores:** Autospores (**structure similar to the parent cell**) are the resting spores which develop into new plants **inside the mother cell**, *e.g.*, *Chlorococcus*.

(viii) **By exospores and endospores:** In many blue-green algae, protoplast divides to form special type of aplanospores, known as exospores and endospores. The endospores are produced inside the cell (*Dermocarpa* forming four to many) and in exospores the protoplast of the cell comes out through a terminal pore and then cut spores (*Chamaesiphon*).

(C) Sexual reproduction

(i) **Isogamous type:** Here the fusing gametes are morphologically similar but physiologically distinct. In some algae, the gametes of (+) and (–) strains fuse together to form zygospore. Isogametes may be motile (zoogametes), *e.g.*, *Chlamydomonas debaryanum* and *Ulothrix* or non-motile (aplanogametes), *e.g.*, *Spirogyra*.

(ii) **Anisogamous type:** Fusion takes place between **morphologically and physiologically distinct** gametes (anisogametes). Male gamete is smaller and active and female gamete is larger and sluggish, *e.g.*, *Chlamydomonas braunii* and *Pandorina*.

(iii) **Oogamous type:** Most advanced type in which fusion of small biciliate or multiciliate, **active male gamete** with large, **passive female gamete** (retained within the oogonium permanently or upto maturity) takes place and zygote is formed, *e.g.*, *Oedogonium*, *Chlamydomonas coccifera*.

(iv) **Autogamy:** Here two gametes of same mother cell fuse to form zygote, *e.g.*, **diatoms.**

CLASSIFICATION OF ALGAE

Dr. F.E. Fritsch (1935) regarded the **class as a highest grade** in algae (**phyceae**) and on the basis of **pigmentation, product of assimilation and ciliation**, divided algae into 11 **classes:**

1. Chlorophyceae
2. Xanthophyceae
3. Chrysophyceae
4. Bacillariophyceae
5. Cryptophyceae
6. Dinophyceae
7. Chloromonadineae
8. Euglenophyceae
9. Phaeophyceae
10. Rhodophyceae
11. Myxophyceae or Cyanophyceae.

This classification is most simple, accurate, convenient and reliable.

Distinguishing characters of different algal groups

(A) Chlorophyceae or Green algae

360 genera, 5000 sps. Main characters are:

1. Colouring pigments of these algae are just like higher plants, *i.e.*, **Chl.-a, Chl.-b, xanthophylls** and carotenes. These pigments are localized in definite plastids, *i.e.*, **chloroplasts.**

- Different types of chloroplasts are found in Chlorophyceae, *e.g.*, cup-shaped—*Chlamydomonas, Chlorella,* collar shaped or girdle-shaped-*Ulothrix,* spiral—*Spirogyra,* star shaped or stellate—*Zygnema;* reticulate (net like)—*Oedogonium, Cladophora*.

2. Food product of assimilation (reserve food) is starch and sugars.

3. One or more **proteinaceous bodies** (pyrenoids) are present in chloroplasts, which manufacture starch.

4. **Flagella are 2 or 4, are of equal length (isokontae type) and whiplash (acronematic) and are at anterior end.**

e.g., Chlamydomonas, Ulothrix, Spirogyra, Cladophora, Zygnema, Oedogonium (cap cells are distinct), *Volvox,* etc.

- *Cephaleuros virescens*: Causes, **'red rust of tea'** (parasitic green alga).

(B) Bacillariophyceae or 'Diatoms'

chromatiphor

1. Diploid thallus.

2. Chromatophores are **golden brown or yellow.** These are called **'diatoms'** due to presence of an accessory brown pigment called 'Diatomin', other pigments are chl.-a, chl.-c (but not chl.-b), carotenes and xanthophylls.

3. Reserve food materials are **fats or protein (Volutine).**

4. Cell wall **silicified** (called **frustule**) and consists of overlapping halves (epitheca and hypotheca).

5. These are **unicellular** and **non-motile** and the **motile stage in sperms,** generally with a single tinsel (pentonematic) terminal **flagellum.**

Naked is whiplash/Acronematic

6. Production of unique type of spores called auxospores (rejuvenant cells).

7. Pyrenoids present.

e.g., Pinnularia, Melosira, Nitzchia, Navicula, etc.

(C) Phaeophyceae or Brown algae

1. Chromatophores are yellowish brown in colour possessing **xanthophylls** in abundance. **Brown colour is due to presence of** pigment **'fucoxanthin'.** Besides Chl.-a, Chl.-c, carotenes and xanthophylls (not Chl.-b) are present.

2. Photosynthetic products or reserve food materials are **alcohol, fats, polysaccharides, mannitol and laminarin.**

3. **Motile reproductive cells are pear-shaped, biflagellated.** The flagella are of **unequal** lengths and inserted laterally. The one flagellum is directed **forward** and is of **tinsel** type (larger) and second directed backwards, *i.e.*, **whiplash** and smaller.

4. Pyrenoid is present.

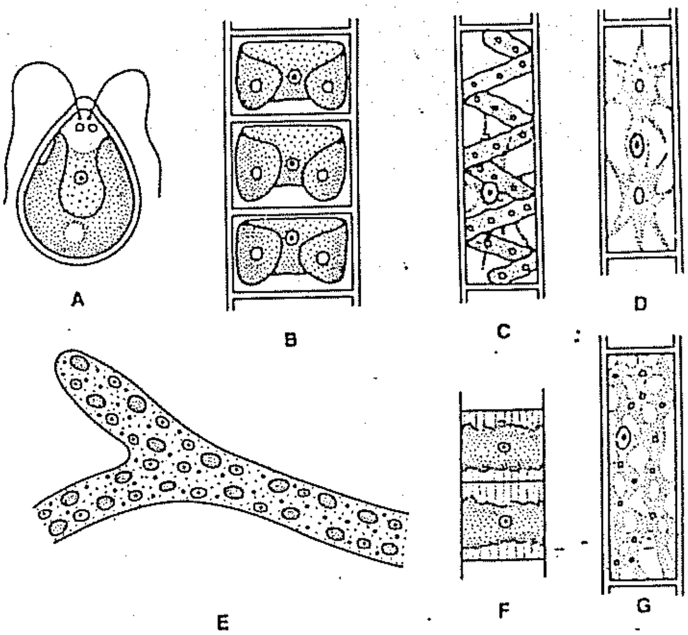


Fig. 10.1. Different shapes of chloroplast in algae: A. Cup-shaped B. Girdle-shaped in *Ulothrix* C. Spiral D. Stellate E. Discoid F. Girdle-shaped in *Stigeoclonium* G. Reticulate

5. Around the nucleus, there are present a number of fucosan vesicles (containing a waste fucosan).

- **Except for 3 members** (*Pleurocladia, Bodanella* and *Heribaudiella*), **all are marine.**

e.g., Fucus, Dictyota, Sargassum, Laminaria, Macrocystis, Ectocarpus, etc. **(These are largest and most rugged of the algae).**

(D) Rhodophyceae or Red algae

These are most showy of sea weeds and are predominantly marine.

1. Colour is red due to presence of a red pigment (r-phycoerythrin) and a **blue pigment (r-phycocyanin)** in the **chromatophores.** These pigments can utilize wavelengths of light (blue-green region of spectrum, *i.e.*, 480–520 nm) not absorbed by chlorophyll. **This enables red algae to grow at greater depths than other plants** (upto 300 ft. below water). In addition to these, chl.-a, chl.-d, carotenes and xanthophylls are present.

2. **Reserve food products are polysaccharides,** *i.e.*, **floridean starch** (which stains red with iodine sol.) and also soluble sugars called **floridoside.**

3. **No flagellation** at all.

4. The prominent plasmodesmata (pit connections) are present,

e.g., Batrachospermum, fresh water red alga, which is not red (generally bluish or olive green), *Polysiphonia, Porphyra, Rhodymenia, Gelidium,* etc.

(E) Myxophyceae or Cyanophyceae or Cyanobacteria or Blue-green algae

1. The pigments are not localized in definite chromatophores, but these are present in peripheral region of protoplast (chromoplasm). The blue-green colour is due to presence of a

highest chromoplasm

phycobilin pigment c-phycocyanin (also c-phycoerythrin). Other pigments are chl.-a, carotenes and unique xanthophylls (myxoxanthin and mucoxanthophyll).

2. Reserve food materials are **cyanophycean starch and proteinaceous substance cyanophycin.**
3. No flagella at all.
4. Sexual reproduction is completely absent.
5. No true nucleus is present (prokaryotic).
6. Cell wall is made of a substance known as mucopeptide (not found anywhere else).
7. Many filamentous forms possess some specialized cells of disputed nature called heterocysts (probably N_2 fixing).

e.g., Oscillatoria, Nostoc, Anabaena, Chroococcus, Synecoccus, Microcystis, etc.

- ○ ***Trichodesmium erythreaum*** **is responsible for red colour of Red Sea.**
- ○ **Members of Cyanophyceae show adaptability to extremes of environment because of their gelatinous sheath, compactness of protein molecules in protoplasm.**

Some common names

1. *Spirogyra* (Chlorophyceae)—**Pond scum or Water silk or Pond silk.**
2. *Chara* (Chlorophyceae)—**'Stone wort'** (globule and nucule are sex organs of *Chara*).
3. *Hydrodictyon* (Chlorophyceae)—**'Water net'.**
4. *Sargassum* (Phaeophyceae)—**'Gulf weed'.**
5. *Batrachospermum* (Rhodophyceae)—**Frog's spawn.**
6. *Chondrus crispus*—**'Irish moss'.**
7. Brown algae—**'Kelps'.**

ECONOMIC IMPORTANCE OF ALGAE

(A) Positive importance

1. Algae as food: People of coastal countries, *e.g.,* China and Japan, have long been using sea weeds and certain other algae as source of food, *e.g., Porphyra, Ulva, Alaria, Chlorella, Rhodymenia* and *Nostoc,* etc. Carbohydrates, inorganic compounds and vitamins (A, C, D and E) are abundant in algae.

- *Porphyra tenera* (red alga) is the most important edible sea weed in Japan (**amanori or nori bread**). It has 30–45% protein and 40–45% carbohydrates, besides vit. A, B, C and Niacin. Also *Alaria, Ulva, Sargassum, Laminaria,* etc. are used as salad. *Ulva* in Europe is called as **Sea lettuce.** *Rhodymenia palmata* is chewed as **tobacco in Scotland** (dulse). *Nostoc commune* is used as food in **China.**
- *Chlorella* (unicellular green alga) is **richer in proteins, lipids and vitamins** and also grows **more quickly** than *Porphyra,* so scientists are doing research to **obtain food from it.** The nutritional value is comparable to mixture of soybeans and **spinach.**
- *Spirulina* is a fast-growing, non-toxic blue-green alga (Cyanobacterium) rich in **proteins, Vitamin B-complex** and minerals, which is cultivated in tanks as important traditional food in some parts of Africa and as a protein-rich animal feed. Nowadays biscuits fortified with powdered *Spirulina* have become very popular.

2. Algae as fodder: *Sargassum* and *Macrocystis* (**largest alga**) are used as food for marine as well as domestic animals.

Besides *Ascophyllum, Fucus, Laminaria* are processed to form cattle feed. In China *Sargassum* is used as fodder and *Rhodymenia* in France.

3. Algae in industries: Algae are useful source of many commercial products, *e.g.,*

(i) **Agar-2:** A jelly-like substance called agar-2 (or agar), is a complex polysaccharide (phycocolloid), is extracted in water from certain sps. of red algae belonging to *Gelidium, Gracillaria* and *Gigartina* and some other genera, this is produced and stored in their cell walls along cellulose. It is gel containing galactose and **sulphate.** Its m.p. is 90–100°F and at lower temperature it solidifies.

- It is used as base in culture media for algae, fungi, bacteria and tissues. Also used as stablizer or emulsifier in food, cosmetics, leather and pharmaceutical industries. It is often given as a laxative in prolapsed stomach.

(ii) **Carrageenin or Caragheen:** Chemically very much like agar and occurs as cell wall polysaccharide esterified with sulphate.

Usually extracted from *Chondrus crispus* and used in pharmaceutical emulsifier, textile, leather, cosmetics and brewing industries.

(iii) **Alignates:** These are salts of alginic acid (phycocolloid) found in the cell wall of phaeophyceae (brown algae), *e.g., Fucus, Laminaria, Macrocystis, Lessonia, Ecklonia, Cystoseira,* etc. **Flame proof fabrics** as well as plastic articles are prepared from alginates. Alginic acid can stop bleeding and thus used as highly efficient gauze in internal operations. Also used as gelling agents in confectionary, dental creams, powders, paints and ice-cream.

(iv) **Diatomite:** It is a rock-like deposit formed from siliceous frustules (cell walls) of past diatoms (diatomaceous earths). It is a whitish substance, porous and insoluble and hence suited for filters for oil and clearing solvents. As it is fire-proof, so used in preparation of high temp. furnaces. Also used in insulation of refrigerators, sound-proof rooms, in packing corrosive chemicals, in manufacture of dynamite, a constituent of some tooth powders, automobile and silver polishes, etc.

- ○ Silicon dioxide (SiO_2) is present in cell walls of diatoms, which forms glass after polymerization.

4. Medicinal use: Antibiotic **chlorellin** is obtained from *Chlorella.* It is **crystalline** and active at **120°C.**

Also extracts of *Cladophora, Lyngbya* kill strains of *Pseudomonas* and *Mycobacterium. Nitella* causes death of mosquitoes in ponds and hence used in control of malaria.

5. In agriculture: Myxophycean members, *e.g., Nostoc, Anabaena,* etc.,convert atmospheric N_2 into nitrogen compounds, which are absorbed by higher plants.

Dr. R.N. Singh (1961) demonstrated that blue-green algae can be used to reclaim saline and alkaline waste lands in various parts of India.

Sea weeds, being rich in K, P, trace elements and growth substances are used as fertilizers by coastal people, *e.g.*, *Fucus*, *Lithophyllum* and *Lycophyllum*, etc.

6. Sewage disposal: Sewage oxidation ponds have been created for its complete oxidation into mineral components. Such ponds support luxuriant growth of unicellular algae, *e.g.*, *Chlorella*, *Chlamydomonas*, *Scenedesmus*, etc. These help in bacterial decomposition by providing O_2.

7. Algae in biological research: Recent knowledge of photosynthesis is based on research carried on *Chlorella* (unicellular green alga).

Acetabularia and *Valonia* are used in research to study nucleo-cytoplasmic interactions.

8. Algae in space travels: A spaceman will need a device to get rid of CO_2 and other body wastes and will require sources of O_2 and food. So *Chlorella*, *Synecoccus*, etc., are useful for this purpose and they grow very quickly.

9. Algae as sources of iodine and bromine: A large amount of iodine (mineral element present in thyroxine hormone of thyroid gland) is extracted from kelps (brown sea weeds or members of phaeophyceae) like *Laminaria*, *Ecklonia*, *Fucus*, *Eisenia* and *Ascophyllum*. Similarly red algae like *Rhodomela*, *Polysiphonia* and *Rhodymenia* are sources of bromine.

nuclic cytoplasmc

(B) Harmful Importance

1. Water bloom: Some blue-green and green algae grow over the surface of water bodies in abundance, especially in rainy season, and cause water bloom. On death and decay, these algae give bad smell. Some dinoflagellates (members of class dinophyceae of algae) secrete poisonous or toxic substances.

- Important algae causing water bloom are *Microcystis*, *Chroococcus*, *Oscillatoria*, etc. These deplete the water of O_2 and hence animals like fish are killed.
- Marine algae growing in abundance retard the speed of ships.

2. Diseases: Parasitic algae like *Cephaleuros virescens* (green alga) causes red rust of tea, coffee and *Magnolia*, etc.

CHLAMYDOMONAS

Systematic position

Kingdom — Plantae
Subkingdom — Thallophyta
Division — Algae
Class — Chlorophyceae
Order — Volvocales
Sub-order — Chlamydomonadinae
Family — Chlamydomonadaceae
Genus — *Chlamydomonas*

Habitat

Chlamydomonas is common fresh water, motile unicellular alga present in stagnant rain water, ponds, pools, ditches and on moist soils. It grows mostly in waters rich in ammonium compounds and organic matter. *Chlamydomonas halophila* has been found in salt water. *Chlamydomonas yellowstonensis* is reported from snow in Yellow Stone National Park of America. *C. nivalis* is reported from the red snow in Alpine and Arctic regions. There are about 325 species of *Chlamydomonas*.

Morphology

It is a unicellular green alga with varying:

(i) **Shapes:** *i.e.*, spherical, ovoid, subcylindrical or ellipsoidal. In many species, an anterior papilla-like outgrowth is present.

(ii) **Protoplast:** It is surrounded by a definite layer of cellulose wall and some species have a gelatinous pectic sheath outside the cellulose layer.

(iii) **Chloroplast:** Most of the species have a **single cup-shaped chloroplast**. In *C. reticulata*, chloroplast is **reticulate** whereas in *C. arachne* and *C. steinii*, it is **stellate**, *i.e.*, star-shaped.

(iv) **Pyrenoid:** Generally a single pyrenoid is present in a chloroplast but some of the species have two *(C. debaryana)* or several *(C. gigantea, C. sphagnicola)* or may be absent *(C. reticulata)*. Pyrenoid is made of **protein** surrounded by starch plate or starch grains and it is the centre of starch formation.

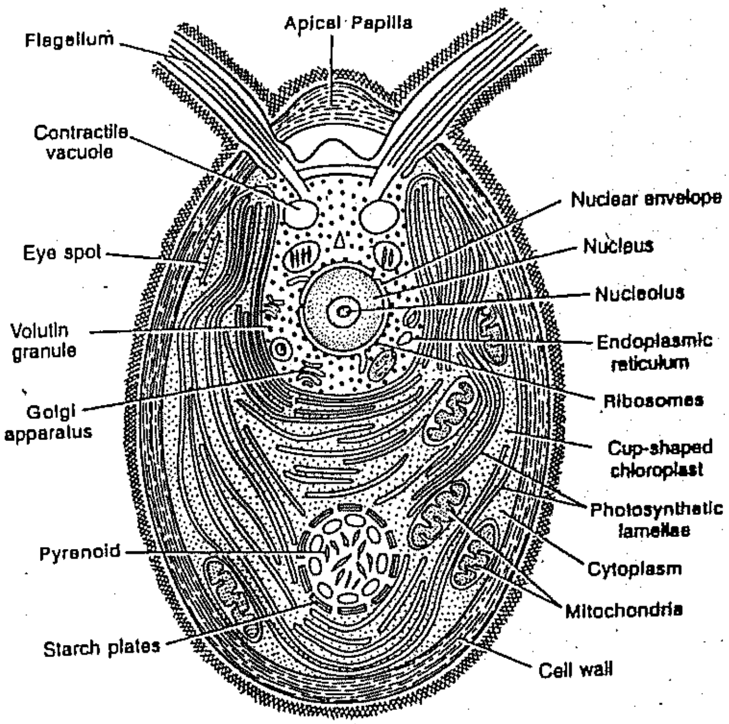


Fig. 10.2. Typical structure of *Chlamydomonas* cell

(v) **Flagella:** At the anterior end arise two flagella, which come out through the same or separate canals. The flagellum arises from a tiny basal granule, the **blepharoplast**. The flagella are **acronematic** (whiplash) and of equal length, connected together by a transverse fibre called **paradesmose** which is attached to intra-nuclear centrosome of the nucleus by rhizoplast.

A tiny spot of an orange or reddish coloured spot known as **stigma** or **eye spot** (contains carotenoides) lies at the anterior end. It is a photoreceptive organ associated with the direction of the movement.

The cell is bounded by the cell membrane and cell wall, which is thickened in the anterior portion. Each flagellum shows 9 + 2 pattern of structure. The chloroplast is surrounded by a unit membrane **containing lamellae** in pairs forming a disc. The number of discs occur in **stacks** ranging from 2–20. Each individual has a single nucleus lying in the colourless cytoplasm. Other structures include the mitochondria, endoplasmic reticulum and dictyosomes.

Autotrophic nutrition is found in *Chlamydomonas*.

Reproduction

Both asexual and sexual reproduction take place in *Chlamydomonas*.

(A) Asexual reproduction

The various modes of asexual reproduction are:

(a) **By zoospores: Under favourable conditions**, the protoplasm of each vegetative cell undergoes repeated longitudinal divisions either into 2 or 4 (rarely 8 or 16) daughter protoplasts. Before division the parent cell retracts its flagella and assumes a spherical shape. After the last division, each protoplast secretes cell wall and develops neuromotor apparatus (flagella, eyespot and contractile vacuoles). The daughter cells are released by rupture of the cell wall. Process of division is repeated every 24 hours and by the end of week about **20,00,000 individuals** are produced **from one parent plant.**

(b) **By aplanospore formation:** Sometimes the protoplast withdraws from parent wall, rounds up and develops into thin walled non-motile spore called **aplanospore** which may either germinate directly or divide to produce zoospores, *e.g., C. caudata.*

(c) **By hypnospores:** In some species like *C. nivalis*, protoplast withdraws from the cell wall, rounds up and develops into a thick-walled spore called hypnospore. These usually develop red colour due to **haematochrome** pigment.

(d) **By palmella stage:** Sometimes the spores are unable to come out. The parent cell wall gelatinises and forms a matrix around the daughter protoplasts. Divisions and redivisions of daughter protoplasts produce an amorphous colony with thousands of cells. On approach of favourable conditions all cells of such palmella stages (named after the genus *Palmella*) develop flagella and become motile and escape from the gelatinous matrix.

(B) Sexual reproduction

It occurs under certain unfavourable conditions as poor supply of nitrogen. Some species of *Chlamydomonas* are **homothallic** while others are **heterothallic**. Gametic fusion may be **isogamous, anisogamous** or **oogamous**, *i.e.*, sexual reproduction ranging from isogamy to anisogamy to oogamy occurs in the same genus *Chlamydomonas*.

(a) **Isogamous reproduction:** It is the most common method of reproduction in *Chlamydomonas*. Each cell may produce **8, 16, 32, or 64** biciliated gametes which belong to either of two opposite mating types and are referred as +ve or −ve strains which fuse to form a zygote. **Such a type of sexual reproduction which involves the fusion of gametes alike in size, form and structure is called isogamy.**

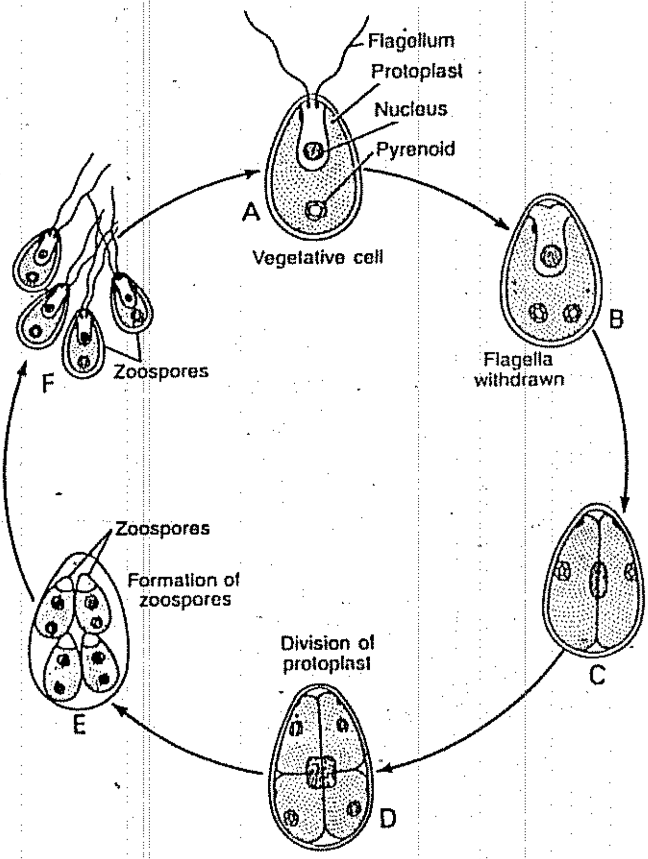


Fig. 10.3. Zoospore formation in *Chlamydomonas*

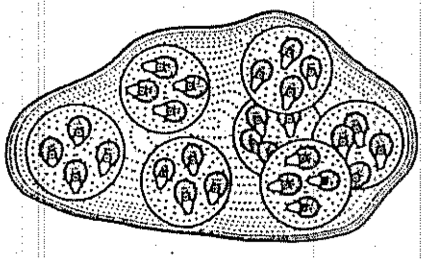


Fig. 10.4. Palmella stage in *Chlamydomonas*

In *C. longistigma*, the gametes are naked (gymnogametes) while in *C. media* the gametes become clothed with a wall just before their emergence from the cell (calyptogametes). Generally in most of the isogamous species any vegetative cell may function as gamete.

(b) **Anisogamous reproduction:** In this type of reproduction, the fusing gametes are not similar, hence are called anisogametes, *e.g.*, in *C. braunii*, 2–4 large female gametes are formed in one cell and 8–16 small male gametes are formed in another cell. The male and female gametes join by their anterior end. At the point of contact, membranes dissolve and contents of male gamete pass into the female gamete. The gametes do not lose their walls at the time of gametic fusion.

(c) **Oogamous reproduction (advanced type):** In oogamous species like *C. coccifera* the male cell (antheridium) divides to form 8, 16 or 32 small biflagellated antherozoids. The large female cell becomes an egg cell or oogonium after loss of flagella. Fusion occurs between antherozoid and egg. Both gametes are with cell wall.

Zygote and its germination: Flagella disappears from the quadriflagellate zygote of isogamous or anisogamous species and a wall is formed around it. The two nuclei fuse and it becomes a spherical structure which undergoes rest. A thick-wall (smooth or spiny) is secreted. The resting zygote enlarges 2–5 times of its original size. Zygote develops a red pigment called haematochrome, however, zygote remains green in *C. euganetos*.

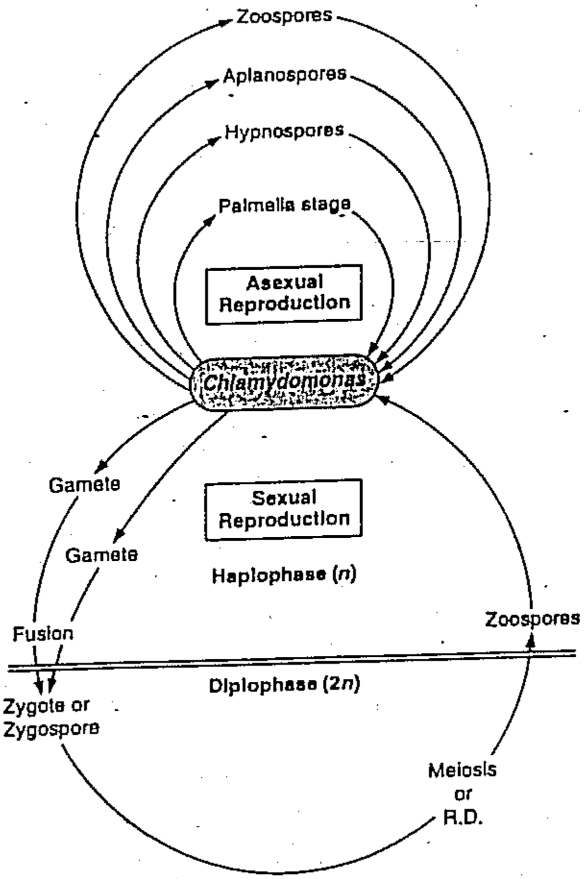


Fig. 10.5. Graphic representation of life cycle of *Chlamydomonas*

On the approach of favourable conditions the zygote germinates into four uninucleate protoplasts after meiosis. The daughter protoplasts are liberated by breaking up the zygote wall.

Usually 4 cells are formed from a single zygote but in some sps. there may be 8 (in *C. reinhardi*) or 16 or 32 (in *C. intermedia*).

- ○ Life cycle in *Chlamydomonas* is haplontic as dominant phase in life cycle is haploid (*n*) and diploid phase is represented only by zygote or zygospore (meiosis or R.D. occurs during germination of zygote).

ULOTHRIX

Systematic position

Kingdom	—	Plantae
Subkingdom	—	Thallophyta
Division	—	Algae
Class	—	Chlorophyceae
Order	—	Ulotrichales
Sub-order	—	Ulotrichineae
Family	—	Ulotrichaceae
Genus	—	*Ulothrix*
Species	—	*zonata*

Habitat

It is a green filamentous alga usually growing in cold fresh water of slow moving streams, pools and springs. *Ulothrix* comprises about 30 species.

- ● *U. flacca* is found in salt marshes (marine in intertidal zone).
- ● *U. implexa* is found as lithophyte. The species occurring in India are *U. zonata*, *U. aequalis*, *U. pectinalis* and *U. variabilis*.
- ● *Ulothrix zonata* is common cold fresh water species.

Plant body

Is an unbranched filament, consisting of numerous cylindrical cells joined end to end. The filaments remain attached to some substratum by means of rhizoidal cell, *i.e.*, showing distinction in base and apex. The basal cell is elongated and colourless known as **holdfast** while the uppermost cell is rounded. Every green cell is squarish or rectangular and consists of cell wall sorrounding the protoplast.

Cell wall consists of two layers. Inner layer is made up of cellulose and outer layer is mostly made up of **protopectin** which is insoluble in water.

- ● Due to presence of **protopectin**, *Ulothrix* filaments appear as wet threads. In the centre of the cell is a nucleus and a girdle or ring-shaped chloroplast. One or more pyrenoids are present in the chloroplast. A vacuole is present, surrounding it is a thin layer of cytoplasm (primordial utricle).

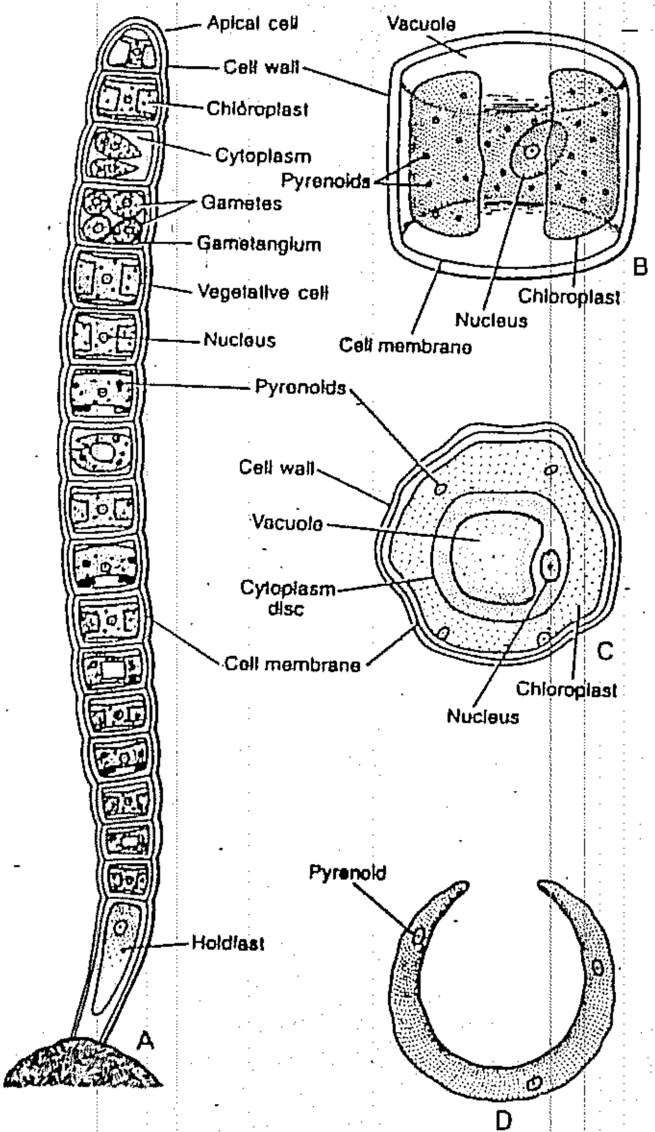

Apical cell
Cell wall
Chloroplast
Cytoplasm
Pyrenoids
Gametes
Gametangium
Vegetative cell
Nucleus
Pyrenoids
Cell membrane
Holdfast
A
Vacuole
Cell wall
Pyrenoids
Chloroplast
Nucleus
Cell membrane
B
Cell wall
Vacuole
Cytoplasm disc
Cell membrane
Chloroplast
Nucleus
C
Pyrenoid
D

Fig. 10.6. *Ulothrix:* A. A vegetative filament B. Enlarged single cell C. Single cell in T.S. D. A single chloroplast

Nutrition

Plants are autotrophic.

Reproduction

Ulothrix reproduces by three methods:

(A) Vegetative reproduction

It takes place by fragmentation. In this process a filament divides into small parts. These smaller fragments grow and give rise to new filaments of *Ulothrix*.

(B) Asexual reproduction

It takes place by the following means:

(i) By **zoospores:** In favourable conditions, each cell produces zoospores except holdfast. Cytoplasm collects in the centre and divides into 2, 4, 8, 16 or sometimes 32 segments. Each segment develops into biflagellate or quadriflagellate zoospores. Each zoospore is uninucleate, pear-shaped with thin cell membrane (zoospores not having cell wall).

Macrozoospores: The bigger zoospores are known as macrozoospores. They are **quadriflagellate** and are 4 or 8 in number per cell.

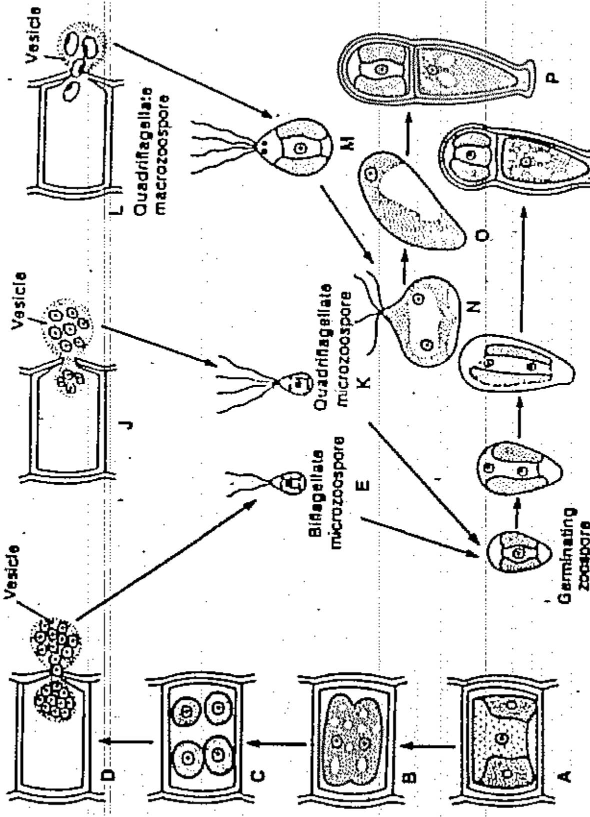

Vesicle
L
Quadriflagellate macrozoospore
M
P
I
O
N
H
Vesicle
J
Quadriflagellate microzoospore
K
Biflagellate microzoospore
E
G
Germinating zoospore
F
Vesicle
D
C
B
A

Fig. 10.7. Formation, liberation and germination of zoospores in *Ulothrix*

Microzoospores: Smaller zoospores are known as microzoospores. These are **bi-** or **quadriflagellate** and their number varies from 4 to 32 per cell.

The zoospores come out into a vesicle, later on the wall disintegrates and macro and microzoospores are liberated free and float in water. Microzoospores attach to substrate by their anterior ends while macrozoospores attach by their posterior narrow ends. After some time zoospores give rise to new individuals.

(ii) By **aplanospores:** Under unfavourable conditions, asexual reproduction takes place with the help of non-motile, mitospores called the aplanospores. In the formation of aplanospores, the contents of a cell separate from the cell wall to form **thin-walled**, nonciliated aplanospores. After liberation, the aplanospore fixes itself to some solid submerged object, manufactures food and elongates. It divides by a transverse wall to form

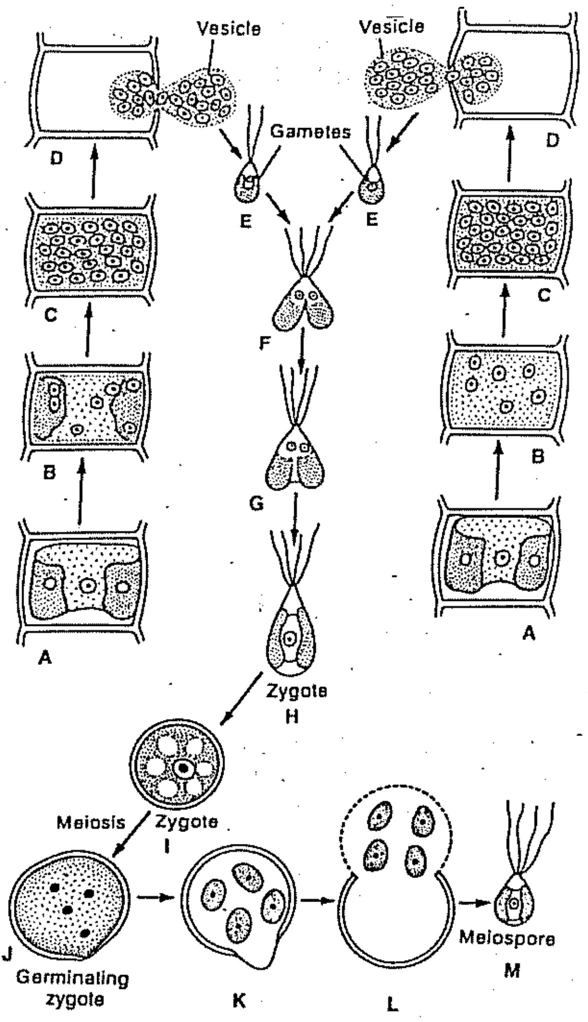

Vesicle
Vesicle
Gametes
D
D
E
E
C
C
F
B
B
G
A
A
Zygote
H
Meiosis
Zygote
I
J
Germinating
zygote
K
L
Meiospore
M

Fig. 10.8. Sexual reproduction in *Ulothrix*

two cells, the upper and the lower. The lower one loses the chloroplast and functions as a rhizoidal cell while the upper one undergoes repeated divisions in one plane and produces a new filament of *Ulothrix*.

(iii) By hypnospores: Under unfavourable conditions, the protoplasm is separated from cell wall and develops into a **thick-walled** structure, the **hypnospore.** On approach of favourable conditions, the hypnospore gives rise to new individual.

(iv) By akinetes: Under unfavourable conditions, certain vegetative cells in the filament develop specially thickened walls and become filled with reserve food materials, these are called akinetes, which on the approach of favourable conditions give rise to new filaments.

(v) By palmella stage: When there is shortage of water, filament lies on the moist soil, each cell divides and redivides with the result that some small rounded cells form a colony which is surrounded by mucilaginous substance which protects it from unfavourable conditions. On the approach of favourable conditions, this mucilaginous substance dissolves and these cells either directly or through zoospores develop into new plants.

(C) Sexual reproduction

It occurs at the end of growing season. *Ulothrix* is heterothallic. Sexual reproduction is of isogamous type. The gametes are motile and biflagellate. Except holdfast each cell of the filament can give rise to 64 to 128 gametes. These gametes are smaller than zoospores. On dehiscence of gametangium, the gametes come out in a bag-like structure and float on water. When two gametes of (+) and (–) strain come together, they fuse and a quadriflagellate zygospore is formed which after floating for sometime on water, rests on the bottom of the pond. At this time, its four flagella disintegrate and a wall is formed surrounding it from all sides. After taking a rest for long period it divides meiotically and gives

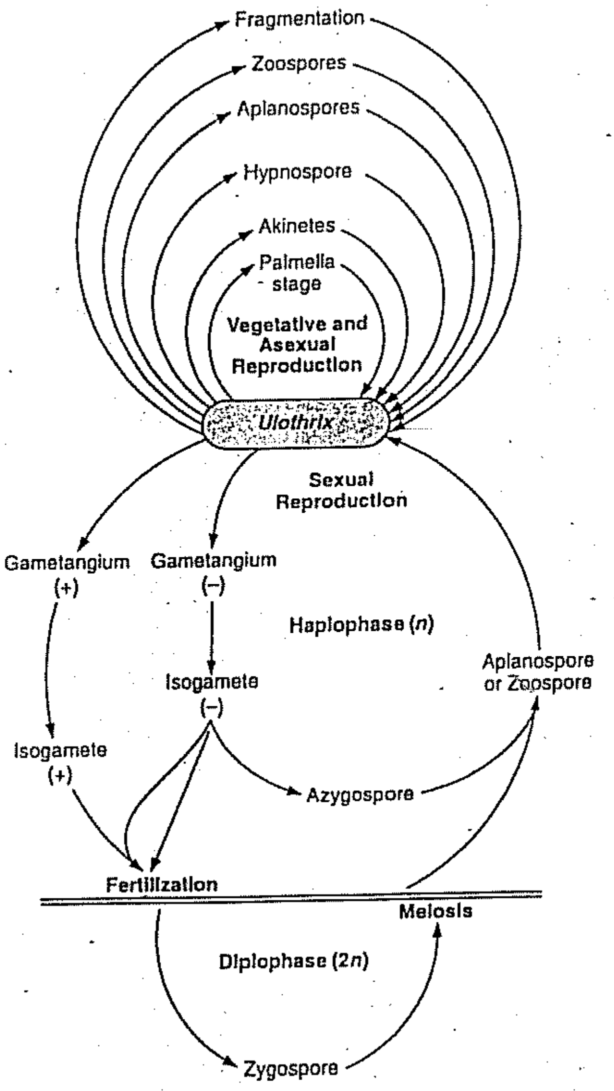

Fragmentation
Zoospores
Aplanospores
Hypnospore
Akinetes
Palmella
stage
Vegetative and
Asexual
Reproduction
Ulothrix
Sexual
Reproduction
Gametangium
(+)
Gametangium
(–)
Haplophase (n)
Isogamete
(–)
Aplanospore
or Zoospore
Isogamete
(+)
Azygospore
Fertilization
Meiosis
Diplophase (2n)
Zygospore

Fig. 10.9. Graphic representation of life cycle of *Ulothrix*

rise to 16 aplanospores or zoospores. These come out of the sac and give rise to a new plant of *Ulothrix*.

- Life cycle in *Ulothrix* is **haplontic** as dominant phase in life cycle is haplophase (*n*) and diploid phase is represented only by zygote or zygospore, which undergoes R.D. or meiosis during its germination.

SPIROGYRA

Systematic position

Kingdom — Plantae
Subkingdom — Thallophyta
Division — Algae
Class — Chlorophyceae
Order — Conjugales
Sub-order — Zygnemideae
Family — Zygnemataceae
Genus — *Spirogyra*
Species — *condensata*

- *Spirogyra* was discovered by **Link.**

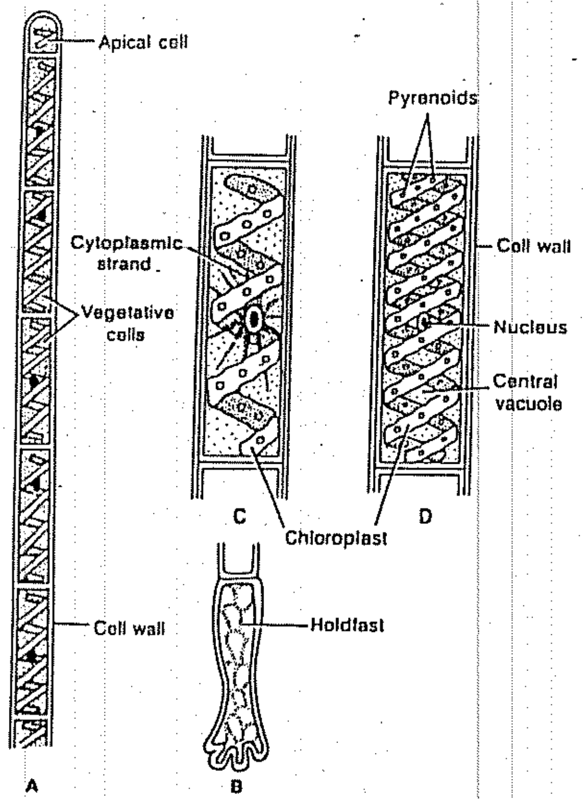


Fig. 10.10. *Spirogyra:* A. A portion of filament B. Holdfast of *S. jogensis* C. Cell with single spiral chloroplast D. Cell with two chloroplasts

Habitat

It is a fresh water olive-green alga found in bright green free floating masses in the still water of fresh water ponds, pools, lakes and also in slow flowing streams called Nadees. Because of the slippery feel of the threads, *Spirogyra* is often called the **pond-scum** or **pondsilk** or **watersilk.** There are about **300** species of which 94 have been reported from India. The common species are *S. jogensis, S. crassata, S. elongata, S. communis, S. condensata, S. parvula, S. microspora, S. sahnii, S. indica,* etc.

Plant body

The plant body is a gametophytic thallus, in the form of a long, silky, unbranched and unattached thread about 1/10 mm across and several centimetres long, often called a filament. Each mature filament is composed of many long identical, cylindrical cells placed end to end in a single row, having no basal distal differentiation. There are few species in which **basal cell** (hapteron) functions as attaching organ and develops rhizoidal outgrowths which assist in attaching the filament to the substratum, *i.e., S. adnata, S. jogensis.* Some other species are also reported having rhizoids, *i.e., S. rhizobrachalis, S. dubia, S. rhizopus* and *S. affinis.*

Cell structure

The cells comprising the filament are cylindrical in form and are several times longer than broad. **Cell wall** surrounds the protoplast. It is protective in function and provides definite shape to the cell. There are neither any pores in the wall nor the external markings on it. It consists of two distinct layers. The inner layer is of **cellulose** and the outer is of pectose which gets changed into pectin and this pectin dissolves in water to form a slimy or mucilaginous sheath. (It is sometimes referred to as third layer.)

The protoplast is differentiated into plasma membrane, cytoplast, nucleus, chloroplast with pyrenoids and a large central vacuole. The **plasma membrane** is differentially permeable and surrounds the cytoplast. The **cytoplast** encloses a large central vacuole filled with cell sap which is rich in tannins, organic and inorganic compounds. This vacuole is separated from the surrounding cytoplast by a thin semipermeable membrane, the **tonoplast** and a peripheral layer of cytoplast enclosing this vacuole is known as **primordial utricle.**

Chloroplasts

Embedded in the cytoplast and parietal in position are the chloroplasts which vary in number in different species from **one to fifteen in each cell.** Single chloroplast was recorded in *S. venkataramanii.* Chloroplasts run in **spiral manner** and **anticlockwise** direction from one end to the other.

- **(Because of this spiral manner, the genus takes its name).**

Pyrenoids are situated in the chloroplasts. They lie **equidistant** from one another and are the centres of starch formation. The cell has a single large nucleus and in addition has numerous dictyosomes, endoplasmic reticulum and mitochondria.

- All the cells in the free floating species of *Spirogyra* are alike, no differentiation into apex and base. Each cell can synthesize its own food, respire, divide and reproduce. Thus the organism may be looked upon as a 'colony of independent cells.'

Nutrition

Spirogyra is autotrophic.

Growth in *Spirogyra* is intercalary or diffused.

Reproduction

In *Spirogyra*, reproduction takes place by three methods:

1. Vegetative reproduction

Under exceptionally favourable conditions, *Spirogyra* multiplies by the method of **fragmentation.** It involves the breaking of the filament into segments or living cells called fragments. Each fragment may consist of a few living cells or a single cell. By repeated cell division and growth, a new filament is formed.

- Some species develop H-shaped pieces (*S. colligata*).

Fragmentation may be brought about in the following ways:

(a) Through accidental breaking resulting from mechanical injury.

(b) Softening and subsequent dissolution of middle lamella of the septa.

(c) Due to sudden change in the temperature and acidity of water.

2. Asexual reproduction

Normally asexual reproduction is absent in *Spirogyra.*

It takes place only in some species. It is of 3 types:

(i) **By aplanospores:** Only few species of *Spirogyra* are known to multiply by means of aplanospores. *S. aplanospora* and *S. karnalae* reproduce by means of aplanospores. These are rounded or ovoid bodies produced singly per cell. They are formed by the contraction of protoplast followed by the secretion of a thin-wall around it. They are liberated by the decay of parent cell wall and germinate directly to grow into a new plant.

(ii) **By azygospores (parthenospores):** On failure in fusion of two gametes in *S. daedalea*, both the gametes develop into azygospores. Under unfavourable conditions, the filaments of *S. varians* placed in sugar solution develop parthenospore or azygospore.

(iii) **By akinetes:** Under unfavourable conditions, the cells of a filament develop into thick-walled structures known as akinetes which under favourable conditions give rise to new plants. The thick-wall is made up of cellulose and pectin, *e.g.*, *S. farlowi.*

3. Sexual reproduction

It takes place towards the end of growing season usually in the late spring. It commences when the filaments are well mature and have stored sufficient food. The external conditions which favour the process are:

(a) Nitrogen deficiency

(b) The change in pH of the aquatic medium on alkaline side.

The sexual reproduction in *Spirogyra* is called **conjugation.** It involves the fusion of two **morphologically identical** but physiologically dissimilar nonciliated gametes. For development of gametes, some of the cells start to act like male and female gametangia in which the cell contents become separated from the cell wall, shrink and ultimately convert into gametes. The fusion of these gametes takes place by the following 2 methods:

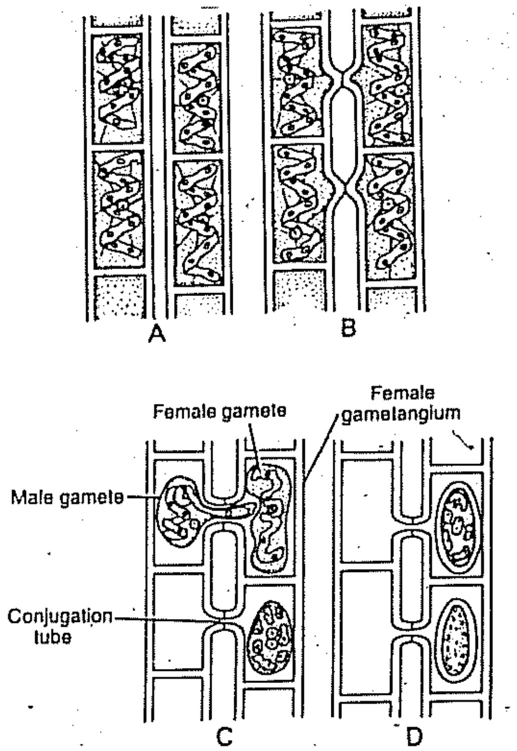


Fig. 10.11. A–D. Sexual reproduction showing scalariform conjugation in *Spirogyra*

(i) **Scalariform** conjugation (ii) **Lateral** conjugation.

(i) **Scalariform conjugation:** It takes place during the night and between the recently divided cells of the conjugating filaments. The participating filaments of the same species of *Spirogyra* come together and lie side by side, parallel to each other and become surrounded by a gelatinous matrix and soon outgrowths or papillae arise usually from one of each pair of opposite cells towards the other. The middle wall between these disintegrates and a conjugation tube is formed and both these cells are termed as **aplanogametangia.**

The conjugation tube between the two filaments looks like a ladder, through which gamete from one of the gametangia passes through to fuse with the passive gamete of another filament. The gametes are formed singly and both **active and passive gametes** are considered **male and female** gametes respectively. The fusion of both kinds of gametes with each other results into formation of **zygospore.** In the beginning, zygospore is greenish but simultaneously chloroplasts of male and female gametes disappear due to which zygospore does not remain green.

The zygospore is differentiated into three layers, the outer exospore which is thin, the middle mesospore which is a thick layer of cellulose, chitinized and pale yellow to brown in colour, and inner endospore which is thin and cellulose in nature.

Parthenogenesis: In some species of *Spirogyra, i.e., S. daedale, S. groenlandica, S. mirabilis,* gametes fail to fuse, they secrete their own independent thick-walls and these asexual zygospores are known as parthenospores which grow into new plants.

(ii) Lateral conjugation: It takes place between two nearest cells of the same filament. Both male and female gametes are found in same filament. It is of two types:

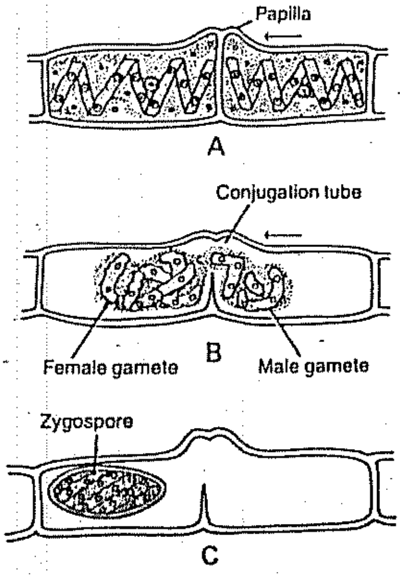

Papilla
A
Conjugation tube
Female gamete
B
Male gamete
Zygospore
C

Fig. 10.12. Sexual reproduction showing lateral (indirect) conjugation in *Spirogyra*

(a) Indirect lateral conjugation: It is commonly reported in *S. affinis* and *S. tenuissima.* Two outgrowths appear on both sides of a transverse septum of two adjacent cells which later on form a conjugation tube. Of the two cells, one behaves as male gametangium from which gamete passes through the tube into female gametangium. By fusion, zygospore is formed. Thus in each second cell of a filament zygospore is formed.

(b) Direct lateral conjugation: It is reported in *S. jogensis.* In this type of conjugation, the male gamete after passing through an aperture in the transverse septum of adjoining gametangium enters the female gametangium and fuses to form a zygospore.

Germination of zygospore: After disintegration of wall of gametangium, the zygospore becomes free and on favourable conditions, its nucleus undergoes reduction division. Four nuclei are formed, out of which three disintegrate. As a result of absorption of water, the external layer of the wall bursts out and protoplasm comes out, the inner layer still surrounds the protoplasm. The new cell undergoes transverse divisions continuously to form a new filament.

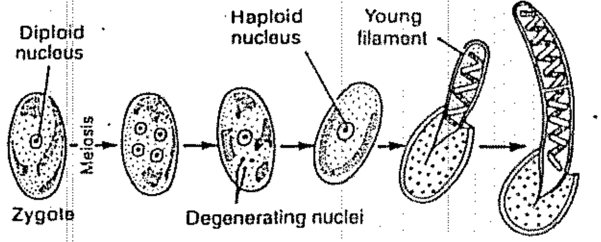

Diploid nuclous
Haploid nucleus
Young filament
Meiosis
Zygote
Degenerating nuclei
A
B
C
D
E
F

Fig. 10.13. Germination of zygospore (zygote) and formation of a young filament in *Spirogyra*

- Thus in the life cycle of *Spirogyra,* there is no flagellate phase.
- Life cycle in *Spirogyra* is **haplontic** as dominant phase in life cycle is haploid (n) and diploid phase is represented by only zygospore and it undergoes R.D. or meiosis (zygotic meiosis).

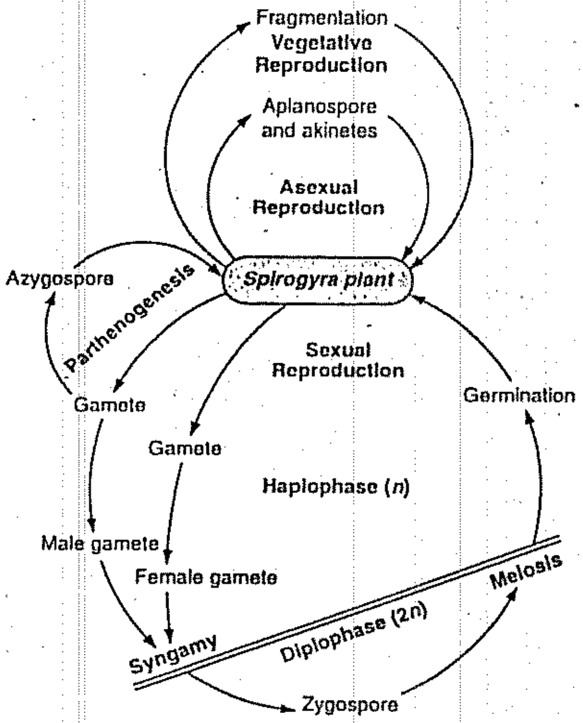

Fragmentation
Vegetative
Reproduction
Aplanospore
and akinetes
Asexual
Reproduction
Azygospore
Parthenogenesis
Spirogyra plant
Sexual
Reproduction
Gamete
Gamete
Germination
Haplophase (n)
Male gamete
Female gamete
Meiosis
Syngamy
Diplophase (2n)
Zygospore

Fig. 10.14. Graphic representation of the life cycle of *Spirogyra*

MULTIPLE CHOICE QUESTIONS

1. Study of algae is known as: (CET Karnataka 2002)
   (a) Mycology (b) Mycetology
   (c) Phycology (d) None of these
2. Term 'Algae' was given by:
   (a) Lamarck (b) Fritsch
   (c) Linnaeus (d) A.P. de Candolle
3. Algae are:
   (a) Chlorophyllous cryptogams
   (b) Non-chlorophyllous cryptogams
   (c) Chlorophyllous phanerogams
   (d) Non-chlorophyllous phanerogams
4. Sex organs in algae are generally:
   (a) Unicellular and jacketed
   (b) Unicellular and non-jacketed
   (c) Multicellular and jacketed
   (d) None of the above
5. Which of the following is not a character of algae?
   (a) Lack vascular tissue
   (b) Little differentiation of true tissue
   (c) No embryo formation
   (d) None of the above
6. Who is called 'Father of modern Algology in India'? (PMET Punjab 2003)
   (a) R.N. Singh (b) Y. Bhardwaj
   (c) F.E. Fritsch (d) M.O.P. Iyenger
7. Terrestrial alga, '*Fritschiella*' was discovered by:
   (a) Fritsch (b) Iyenger
   (c) Y. Bhardwaj (d) Desikachary
8. Role of blue-green algae in reclamation of saline usher land in India was shown by:
   (a) Iyenger (b) Balakrishnan
   (c) R.N. Singh (d) Y. Bhardwaj
9. Which of the following is not an algologist?
   (a) Desikachary (b) H.D. Kumar
   (c) Ghose (d) None of these
10. Which of the following is a parasitic alga?
    (a) *Zoochlorellae* (b) *Oedogonium*
    (c) *Cephaleuros* (d) *Protoderma*
11. Which of the following is a cryophytic alga?
    (a) *Haematococcus nivalis*
    (b) *Scotiella*
    (c) *Chlamydomonas yellowstonensis*
    (d) All of the above
12. 'Red snow' is caused by:
    (a) *Chlamydomonas nivalis* (b) *Haematococcus nivalis*
    (c) Both (a) and (b) (d) None of these
13. 'Green snow' in Europe is caused by:
    (a) *Chlamydomonas nivalis*
    (b) *Chlamydomonas yellowstonensis*
    (c) *Scotiella*
    (d) None of the above
14. 'Black snow' is caused by:
    (a) *Scytonema* (b) *Scotiella*
    (c) *Raphidonema* (d) Both (b) and (c)
15. *Nostoc* and *Anabaena* live symbiotically in:
    (a) *Anthoceros* thallus (b) *Azolla* (fern)
    (c) Coralloid root of *Cycas* (d) All of these
16. Blue-green algae which live endophytically in protozoans are called:
    (a) Cyanophages (b) Cyanobacteria
    (c) Plasmids (d) Cyanallae
17. Which is endozoic alga?
    (a) *Cladophora* (b) *Zoochlorellae*
    (c) *Protoderma* (d) None of these
18. 'Red Sea' is red due to: (Raj. PMT 2001)
    (a) *Chlamydomonas nivalis*
    (b) *Haemotococcus nivalis*
    (c) *Trichodesmium erythraeum*
    (d) *Scotiella*
19. Which alga is commonly known as 'Water net'?
    (a) *Chara* (b) *Ulothrix*
    (c) *Hydrodictyon* (d) None of these
20. Simplest non-motile unicellular coccoidal algae is:
    (a) *Chlorella* (b) *Diatom*
    (c) *Chroococcus* (d) None of these
21. Unbranched floating filaments are found in:
    (a) *Ulothrix* (b) *Oedogonium*
    (c) *Spirogyra* (d) *Chlamydomonas*
22. Thallus differentiated into prostrate and erect system is called:
    (a) Heterotrichous (b) Siphonous
    (c) Pseudoparenchymatous (d) Parenchymatous
23. 'Frog's spawn' alga is: (DPMT 2003)
    (a) *Macrocystis* (b) *Sargassum*
    (c) *Batrachospermum* (d) None of these
24. Highest number of chromosomes ($n = 592$) in algae is in:
    (a) *Porphyra* (b) *Ulothrix*
    (c) *Netrium* (d) None of these
25. Non-flagellated, thin-walled spores in algae are called:
    (a) Zoospores (b) Hypnospores
    (c) Aplanospores (d) Zygospores
26. Most advanced group of algae is:
    (a) Cyanophyta (b) Rhodophyta
    (c) Phaeophyta (d) Chlorophyta
27. Most gigantic among algae is:
    (a) *Microcystis* (b) *Macrocystis*
    (c) *Laminaria* (d) *Dictyota*
28. Cyanobacteria, a new name has been given to: (CPMT 2002)
    (a) Myxophyceae (b) Myxomycetes
    (c) Mycoplasma (d) Schizomycetes
29. Hypnospores are for:
    (a) Nutrition (b) Defence
    (c) Reproduction (d) None of these
30. Gametes without a cell wall are called:
    (a) Calyptogametes (b) Coenogametes
    (c) Mitogametes (d) Gymnogametes
31. Autogamy is a characteristic feature of:
    (a) *Chlamydomonas* (b) *Ulothrix*
    (c) *Spirogyra* (d) Diatoms

32. Which alga is the richest source of proteins?
(a) *Porphyra* (b) *Ulva*
(c) *Rhodymenia* (d) *Chlorella*

33. Which of the following is chewed as tobacco in Scotland?
(a) *Nostoc* (b) *Ulva*
(c) *Rhodymenia* (d) *Porphyra*

34. Which of the following is Agarophyte? (CBSE 2003)
(a) *Gelidium* (b) *Gracillaria*
(c) *Gigartima* (d) All of these

35. Irish moss yields an important substance:
(a) Agar-2 (b) Alginate
(c) Caragheen (d) None of these

36. Alginates (alginin), used as highly efficient gauze in internal operations are obtained from cell walls of: (BHU 1999)
(a) Cyanophyceae (b) Phaeophyceae
(c) Rhodophyceae (d) All of these

37. 'Diatomite' is obtained from:
(a) Myxophyceae (b) Bacillariophyceae
(c) Phaeophyceae (d) Rhodophyceae

38. An important antibiotic of algal origin is:
(a) Griseofulvin (b) Chlorellin
(c) Streptomycin (d) All of these

39. Which alga is used in control of 'Malaria'?
(a) *Cladophora* (b) *Nitella*
(c) *Chlorella* (d) None of these

*40. 'Sewage oxidation ponds' have luxuriant growth of:
(a) *Chlorella* (b) *Chlamydomonas*
(c) *Scenedesmus* (d) All of these

41. Which alga is used in space programme to regulate the supply of.........is?
(a) *Chlorella*, CO_2 (b) *Chlorella*, O_2
(c) *Acetabularia*, O_2 (d) *Scenedesmus*, CO_2

42. Which alga is used in biological research?
(a) *Acetabularia* (b) *Chlorella*
(c) *Valonia* (d) All of these

43. 'Water bloom' is generally caused by:
(a) Green algae (b) Blue-green algae
(c) Red algae (d) Brown algae

44. 'Red rust of tea' is caused by: (CPMT 1999)
(a) Bacteria
(b) *Nitella*
(c) *Cephaleuros* (Green alga)
(d) *Cephaleuros* (Blue-green alga)

45. Pioneer to point out the significance of blue-green algae in relation to N_2-fixation is:
(a) Fogg (b) P.K. De
(c) Fritsch (d) R.N. Singh

46. Which of the following lacks 'Chloroplasts'?
(a) Myxophyceae (b) Rhodophyceae
(c) Phaeophyceae (d) All of these

47. Chlorophyceae (green algae) have:
(a) Chl.-a only (b) Chl.-b only
(c) Both (a) and (b) (d) No chlorophyll

48. Cap cells are a distinguishing feature of:
(a) *Ulothrix* (b) *Spirogyra*
(c) *Cladophora* (d) *Oedogonium*

49. Cell wall in green algae consists of:
(a) Cellulose (b) Chitin
(c) Cutin (d) Suberin

*50. Highly silicified cell walls are present in:
(a) Chlorophyceae (b) Phaeophyceae
(c) Bacillariophyceae (d) None of these

51. Auxospores are found in:
(a) Diatoms (b) Green algae
(c) Cyanobacteria (d) All of these

52. Fresh water red alga (which is not red) is:
(a) *Batrachospermum* (b) *Polysiphonia*
(c) *Porphyra* (d) None of these

53. 'Floridean starch' is reserve food material in:
(a) Chlorophyceae (b) Myxophyceae
(c) Phaeophyceae (d) Rhodophyceae

54. Which type of algae grows at maximum depth under water?
(a) Chlorophyceae (b) Myxophyceae
(c) Phaeophyceae (d) Rhodophyceae

*55. Major light absorption bands of phycoerythrin and phycocyanin are:
(a) 480–520 nm (b) 555–565 nm
(c) 670–700 nm (d) 610–625 nm

56. Which are largest and most rugged of algae?
(a) Chlorophyceae (b) Phaeophyceae
(c) Rhodophyceae (d) Bacillariophyceae

57. Which class of algae show adaptability to extremes of environment?
(a) Chlorophyceae (b) Cyanophyceae
(c) Phaeophyceae (d) Rhodophyceae

58. I_2 is obtained from:
(a) Red algae (b) Brown algae
(c) Blue-green algae (d) None of these

59. 'Kelps' are:
(a) Members of rhodophyceae
(b) Members of phaeophyceae
(c) Members of chlorophyceae
(d) None of the above

60. 'Globule' and 'Nucule' are sex organs of:
(a) *Spirogyra* (b) *Oedogonium*
(c) *Chara* (d) *Sargassum*

61. Which is commonly called 'Water silk'? (Kerala PMT 2003)
(a) *Ulothrix* (b) *Spirogyra*
(c) *Chlamydomonas* (d) None of these

*62. Heterocysts are found in:
(a) Cyanophyceae (b) Chlorophyceae
(c) Phaeophyceae (d) Rhodophyceae

63. *Chlamydomonas* is found in:
(a) Fresh, stagnant water (b) Fresh running water
(c) Marine, stagnant water (d) None of these

64. *Chlamydomonas* has chloroplast:
(a) Girdle-shaped (b) Collar-shaped
(c) Cup-shaped (d) None of these

65. Cell of *Chlamydomonas* has:
(a) 2 Anterior acronematic flagella
(b) 2 Posterior acronematic flagella
(c) 2 Anterior pantonematic flagella
(d) None of the above

66. 'Eye spot' or 'stigma' is present in:
(a) *Ulothrix* (b) *Chlamydomonas*
(c) *Spirogyra* (d) None of these

67. The hypnospores in *Chlamydomonas* develop red colour in their wall due to:
(a) Cytochrome (b) Phycoerythrin
(c) Haematochrome (d) None of these

*68. Sexual reproduction ranging from isogamy to anisogamy to oogamy occurs in:
(a) *Ulothrix* (b) *Spirogyra*
(c) *Chlamydomonas* (d) All of these

69. Core of pyrenoid is made of:
(a) Sugar (b) Fats
(c) Protein (d) Lipoprotein

70. Which one is commonly called 'Sea lettuce'?
(a) *Ulva* (b) *Laminaria*
(c) *Porphyra* (d) *Sargassum*

71. Zygospore is a:
(a) Primitive gametophyte (b) Advanced sporophyte
(c) Advanced gametophyte (d) Primitive sporophyte

72. In *Ulothrix* sex differentiation is shown by:
(a) Zoogametes dissimilar in behaviour
(b) Zoospores dissimilar in behaviour
(c) Zoogametes similar in behaviour
(d) Zoospores similar in behaviour

73. Vegetative reproduction in *Ulothrix* and *Spirogyra* occurs by:
(a) Gemmules (b) Death and decay
(c) Fragmentation (d) Gametes

74. Akinete is:
(a) A specially modified rhizoidal cell
(b) A specially modified nutritive cell
(c) A specially modified vegetative cell for reproduction
(d) None of the above

75. *Ulothrix* grows in:
(a) Running water (b) Stagnant water
(c) Both (a) and (b) (d) None of these

76. The species of *Ulothrix* found in salt marshes (Marine) is:
(a) *U. zonata* (b) *U. flacca*
(c) *U. aqualis* (d) *U. pectinalis*

77. The filaments of *Ulothrix* are like 'wet threads' due to:
(a) Cellulose (b) Protopectin
(c) Pectin (d) Chitin

78. Fusing gametes in *Ulothrix* are:
(a) Morphologically different
(b) Physiologically different
(c) Morphologically and physiologically different
(d) Morphologically similar and physiologically different

79. Filaments of *Ulothrix* are:
(a) Brick-shaped (b) Branched
(c) Girdle-shaped (d) Unbranched

80. *Spirogyra* is more advanced than *Ulothrix*, because:
(a) Holdfast is absent in *Ulothrix*
(b) *Spirogyra* has internal fertilization
(c) *Spirogyra* is always heterothallic
(d) *Ulothrix* is unicellular and *Spirogyra* is multicellular

81. Meiosis in *Ulothrix* is: (MPPMT 2002)
(a) Somatic (b) Zygotic
(c) Both (a) and (b) (d) None of these

82. *Ulothrix* is:
(a) Monoecious alga (b) Hermaphrodite alga
(c) Dioecious (d) Saprophytic alga

83. The gametes are similar to zoospores in *Ulothrix* except gametes are:
(a) Smaller in size
(b) Larger in size
(c) No difference in size
(d) Sometimes smaller, sometimes larger

84. *Spirogyra* occurs in:
(a) Running salt water (b) Running fresh water
(c) Stagnant salt water (d) Stagnant fresh water

85. The attached species of *Spirogyra* is:
(a) *S. adnata* (b) *S. jogensis*
(c) Both (a) and (b) (d) All the species

86. No. of chloroplasts per cell of *Spirogyra* is:
(a) One (b) Two
(c) One to fifteen (d) More than 15

87. An alga with no flagellate phase is: (CPMT 2001)
(a) *Oedogonium* (b) *Spirogyra*
(c) *Volvox* (d) *Chlamydomonas*

88. *Spirogyra* is slippery in touch as:
(a) It grows in H_2O
(b) Its cell wall is cellulosic
(c) It has sheath of pectose
(d) None of the above

89. Two fusing gametes of *Spirogyra* are: (B.V. Pune 2003)
(a) Morphologically similar
(b) Morphologically dissimilar
(c) Morphologically and physiologically dissimilar
(d) Morphologically similar and physiologically dissimilar

90. After fertilization, *Spirogyra* filaments lose green colour because:
(a) Zygospores are formed
(b) Zygotes are formed
(c) New filaments are formed
(d) Oil content is deposited

91. Mature zygospores of *Spirogyra* are:
(a) Greenish
(b) Non-green
(c) Sometimes green, sometimes non-green
(d) None of the above

92. Lateral conjugation in *Spirogyra* occurs between:
(a) Different filaments
(b) Two cells of same filaments
(c) Both (a) and (b)
(d) None of the above

93. How many filaments of *Spirogyra* are formed from germination of zygospore?
(a) 1 (b) 2
(c) 3 (d) 4

94. The chlorophyll in *Chlamydomonas* occurs in:
(a) Grana (b) Thylakoid
(c) Pyrenoid (d) Stigma or eye spot

95. In *Chlamydomonas*, gametes are:
(a) Multiflagellated (b) Uniflagellated
(c) Quadriflagellated (d) Biflagellated

96. Most common and advanced type of conjugation in *Spirogyra* is:
(a) Scalariform (b) Indirect lateral
(c) Direct lateral (d) None of these

97. A single *Chlamydomonas* plant can produce aplanospores:
(a) Only one (b) 2–4 aplanospores
(c) Several (d) None of these

98. Algae are best perennated by:
(a) Gamete (b) Palmella stage
(c) Hypnospores (d) Akinetes

99. Zoospores of *Chlamydomonas* differ from flagellate spores produced from zygospores in:
(a) Having 4 flagella (b) Having diploid nucleus
(c) Being mitospores (d) None of these

100. *Chlamydomonas* plant is a:
(a) Parasite (b) Saprophyte
(c) Sporophyte (d) Gametophyte

101. In which sps. of *Chlamydomonas*, oogamy occurs?
(a) *C. braunii* (b) *C. longistigma*
(c) *C. coccifera* (d) *C. media*

102. Azygospore is:
(a) Hapioid (b) Diploid
(c) Triploid (d) Sporophytic

103. Algae are characterized by:
(a) Thalloid plant body (b) Aquatic habitat
(c) Unicelled sex organs (d) Pyrenoid

104. Life cycle of *Chlamydomonas* is:
(a) Haplontic (b) Diplontic
(c) Triphasic (d) None of these

*105. Eye spot in *Chlamydomonas* contains:
(a) Carotenoids (b) Chlorophyll
(c) Haematochrome (d) Xanthophyll

106. *Chlamydomonas* is an indicator of:
(a) High content of organic matter
(b) High content of inorganic matter
(c) Low content of organic matter
(d) Low content of inorganic matter

107. During reproduction the cell of *Chlamydomonas*:
(a) Loses its flagella, becomes non-motile and comes to rest
(b) Retains flagella and starts swimming
(c) Retains flagella and starts dividing
(d) No change

108. *Spirogyra* was discovered by:
(a) Fritsch (b) Iyenger
(c) Link (d) Fogg

109. The most common method of reproduction in *Spirogyra* is:
(a) Fragmentation (b) Scalariform conjugation
(c) Lateral conjugation (d) All of these

110. Each chloroplast in *Spirogyra* bears:
(a) Indefinite pyrenoids equidistant from each other
(b) Definite pyrenoids equidistant from each other
(c) Indefinite pyrenoids at unequal distances
(d) Only 10–20 pyrenoids

111. Which is not characteristic of *Spirogyra?*
(a) Isogamous conjugation (b) Fragmentation
(c) Zoospory (d) None of these

112. *Spirogyra* is named so, because:
(a) Pyrenoid is spirally arranged
(b) Chloroplast is spirally arranged
(c) Plasma membrane is spiral
(d) All of the above

113. Most of algae float in water during day and sink at night, as:
(a) They become buoyant by virtue of their accumulation of O_2 as a result of photosynthesis
(b) They come upto receive sunshine
(c) They become light in weight due to utilization by fish
(d) Become lighter due to loss of food in respiration

114. Spiral of chloroplast in *Spirogyra* is:
(a) Sinistral (b) Dextral
(c) Double helical (d) Circular

*115. Hormogonia are the vegetatively reproducing structures of: **(AIIMS 1999)**
(a) *Ulothrix* (b) *Spirogyra*
(c) *Oscillatoria* (d) *Chlamydomonas*

116. Blue-green algae belong to:
(a) The myxomycetes
(b) The eukaryota
(c) The prokaryota
(d) Neither the eukaryota nor the prokaryota

117. Storage product in Rhodophyceae is: **(BHU 1992)**
(a) Starch and oil (b) Cellulose
(c) Floridean starch (d) Glycogen

118. The shape of chloroplast in *Ulothrix* is: **(CPMT 1992)**
(a) Spiral
(b) Coiled
(c) Collar-like and cylindrical
(d) Circular or elliptical

119. Which of the following produces non-motile gametes?
(a) *Ulothrix* (b) *Spirogyra*
(c) *Anabaena* (d) *Cladophora*

120. *Ulothrix* occurs in:
(a) Running salt water (b) Stagnant fresh water
(c) Running fresh water (d) Stagnant salt water

121. The branch of Botany dealing with algae is known as:
(a) Taxonomy (b) Phycology
(c) Microbiology (d) Mycology

122. Replicate septum of *Spirogyra* is characterised by:
(a) Peg-like protuberance (b) A spiral outgrowth
(c) Ring-like outgrowth (d) A perforation in the septa

123. Mode of sexual reproduction in *Spirogyra* is:
(a) Anisogamy (b) Isogamy
(c) Oogamy (d) Heterogamy

124. Diplohaplobiontic sexual reproduction cycle is seen in:
(a) *Ulva* (b) *Sargassum*
(c) *Spirogyra* (d) *Oedogonium*

125. The central portion of the protoplast in *Oscillatoria* is called:
(a) Centrosome (b) Nucleoplasm
(c) Centroplasm (d) Chromoplasm

126. In *Spirogyra* meiosis takes place in: (CPMT 1993)
(a) Zygospore germination (b) Spore formation
(c) Gamete formation (d) Akinete formation

127. Red colour of red algae is due to:
(a) r-phycoerythrin (b) r-phycocyanin
(c) Carotenoids (d) Xanthophylls

128. The simplest among green plants are:
(a) Algae (b) Fungi
(c) Bacteria (d) Protozoa

129. *Spirogyra* occurs in:
(a) Stagnant salt water (b) Running salt water
(c) Stagnant fresh water (d) Running fresh water

130. *Spirogyra* differs from moss protonema in having: (BHU 1991)
(a) Pyrenoid (b) Branched filament
(c) Discoid chloroplast (d) Rhizoidal branches

131. Storage product of most of the algae is:
(a) Glycogen (b) Fat
(c) Cellulose (d) Starch and oil

132. Which of the following is found most rarely near the sea coast?
(a) Mosses (b) Green algae
(c) Red algae (d) Brown algae

133. *Chlorella* is used in space programmes for the supply of:
(a) CO_2 (b) O_2
(c) N_2 (d) H_2S

134. An example of agarophyte is:
(a) *Dictyota* (b) *Nostoc*
(c) *Gelidium* (d) *Fucus*

135. Floridean starch as a stored photosynthate is present in:
(a) Red algae (b) Green algae
(c) Blue-green algae (d) Brown algae

136. Epidermis with stomata is:
(a) Present in algae
(b) Absent in algae
(c) Present or absent in algae
(d) Not known

137. The name "Gulf weed" is used for:
(a) *Batrachospermum* (b) *Fucus*
(c) *Sargassum* (d) *Chlamydomonas*

138. Phycoerythrin is present in:
(a) *Euglena* (b) *Polysiphonia*
(c) *Chlamydomonas* (d) *Fucus*

139. The organ by which *Ulothrix* is attached to its substratum is called a:
(a) Rhizoid (b) Holdfast
(c) Trichome (d) Root

140. Palmella stage occurs in:
(a) *Spirogyra* (b) *Aspergillus*
(c) *Ulothrix* (d) *Cystopus*

141. Fairly good yield of rice can be had over a number of years without adding any nitrogenous manure because:
(a) They require very minute quantities of nitrogen
(b) There are nitrogen-fixing blue-green algae in the rice fields
(c) Rice plants do not require any nitrogen
(d) Their roots have nitrogen-fixing bacteria associated with them

142. The zoospores in *Ulothrix* are liberated by the: (CPMT 1990)
(a) Degeneration of lateral walls
(b) Formation of a pore in lateral wall
(c) Gelatinization of lateral walls
(d) Gelatinization of all the cell walls

143. Which of the following alga shows heterotrichous habit?
(a) *Chlamydomonas* (b) *Ulothrix*
(c) *Stigeoclonium* (d) *Oedogonium*

144. Which of the following are autotrophic?
(a) Protozoa (b) Algae
(c) Fungi (d) Viruses

145. In *Spirogyra*, cells take essential salts and water by means of:
(a) Chloroplast (b) Pyrenoid
(c) Cytoplasm (d) Nucleus

146. Zygote formed in *Ulothrix* is initially:
(a) Uniflagellate (b) Biflagellate
(c) Quadriflagellate (d) Aflagellate

147. Which of the following chlorophylls is common in Bacillariophyceae and Phaeophyceae, but lacking in Rhodophyceae?
(a) Chlorophyll-a (b) Chlorophyll-b
(c) Chlorophyll-c (d) Chlorophyll-d

148. The alga, which is used as a food in space flights, is: (BHU 1992)
(a) *Ulothrix* (b) *Spirogyra*
(c) *Nostoc* (d) *Chlorella*

149. *Vaucheria*, a siphonaceous alga, belongs to:
(a) Chlorophyceae (b) Xanthophyceae
(c) Charophyceae (d) Cyanophyceae

150. Heterocysts are found in:
(a) *Cystocarp* (b) *Aspergillus*
(c) *Nostoc* (d) *Ulothrix*

151. Protein-rich alga is:
(a) *Scytonema* (b) *Spirulina*
(c) *Chlamydomonas* (d) *Cosmarium*

152. In *Ulothrix*, food is stored in the form of:
(a) Protein (b) Starch
(c) Pyrenoid (d) Lipid

*153. Red oceanic tides are due to:
(a) Blue-green algae (b) Red algae
(c) Dinophyceae (d) Diatoms

154. An alga which is used in space flights for regular supply of oxygen is: **(CET Karnataka 1993)**
(a) *Anabaena* (b) *Nostoc*
(c) *Chlorella* (d) *Chlamydomonas*

155. Heterocysts are found in: **(VVMC Safdarjung 2001)**
(a) Prokaryotes (b) *Neurospora*
(c) *Nostoc* (d) *Ulothrix*

156. The sexual reproduction in *Spirogyra* is:
(a) Oogamous (b) Anisogamous
(c) Cleistogamous (d) None of these

157. Food is stored in *Spirogyra* in:
(a) Chloroplast (b) Pyrenoid
(c) Vacuole (d) Cytoplasm

158. A group of autotrophic plants kept under thallophyta is:
(a) Algae (b) Fungi
(c) Virus (d) Bacteria

159. No growth of *Spirogyra* can occur in:
(a) River (b) Pond
(c) Stream (d) Sea

160. Scalariform conjugation occurs in: **(CPMT 1991)**
(a) *Ulothrix* (b) *Oedogonium*
(c) *Spirogyra* (d) *Chlamydomonas*

161. In biotechnological studies, the alga that is exploited as a rich source of protein is: **(BHU 1990)**
(a) *Spirogyra* (b) *Spirulina*
(c) *Chlamydomonas* (d) *Scytonema*

162. Which of the following is a prokaryote?
(a) Yeast (b) A blue-green alga
(c) A green alga (d) *Euglena*

163. Filaments of *Ulothrix* produce:
(a) Anisogametes (b) Isogametes
(c) Heterogametes (d) None of these

164. On germination, each *Spirogyra* zygospore gives rise to:
(a) Four plants (b) Three plants
(c) Two plants (d) One plant

165. Filaments of *Ulothrix* are:
(a) Unbranched (b) Branched
(c) Brick-shaped (d) Girdle-shaped

166. In which of the following auxospores are found?
(a) *Chlamydomonas* (b) *Ulothrix*
(c) Diatoms (d) *Oedogonium*

167. Water bloom is generally caused by:
(a) *Hydrilla* (b) Bacteria
(c) Blue-green algae (d) Green algae

168. Reproduction in *Anabaena* is by means of:
(a) Hormogonia (b) Aplanospore
(c) Akinete (d) Autospore

169. Cyanobacteria resemble bacteria in having:
(a) 70S ribosomes (b) Naked DNA
(c) Peptidoglycan wall (d) All of these

170. A red alga which is not red in colour:
(a) *Polysiphonia* (b) *Gracilaria*
(c) *Batrachospermum* (d) None of these

171. *Ulothrix* produces:
(a) Quadriflagellate macrozoospores only
(b) Quadriflagellate microzoospores only
(c) Biflagellate macrozoospores only
(d) All the three types of zoospores stated above

172. In semi-drying conditions, *Ulothrix* produces:
(a) Akinete (b) Zoospores
(c) Gametes (d) Palmella

173. The number of flagella in the gametes of *Ulothrix* is:
(a) Six (b) Four
(c) Two (d) None of these

174. The chloroplast of *Ulothrix* is:
(a) Ribbon-shaped (b) Cup-shaped
(c) Reticulate (d) Girdle-shaped

175. In *Spirogyra* the reduction division takes place:
(a) In the vegetative cell
(b) At the time of formation of isogametes
(c) In the zygospores
(d) In the new filament

176. In which of the following plants archegonium is absent?
(a) *Spirogyra* (b) *Funaria*
(c) *Pteris* (d) *Cycas*

177. In *Spirogyra*, meiosis occurs:
(a) During conjugation
(b) During vegetative reproduction
(c) During formation of gametes
(d) As the zygospore germinates

178. Cyanobacteria differ from bacteria in having:
(a) Ribosomes (b) Naked DNA
(c) Peptidoglycan wall (d) Chlorophyll-a

179. Agar-agar is obtained from: **(CPMT 1993)**
(a) Bacteria (b) Fungi
(c) *Gelidium* (d) Virus

180. Cortication of apex is found in:
(a) *Oedogonium* (b) *Vaucheria*
(c) *Cladophora* (d) *Chara*

181. Which of the following algae shows best origin and evolution of sex?
(a) Brown algae (b) Red algae
(c) Blue-green algae (d) Green algae

182. Unilamellate thylakoids are found in:
(a) *Chlamydomonas* (b) *Euglena*
(c) *Ectocarpus* (d) *Nostoc*

183. Agar-agar, which is prepared from certain algae, is used as:
(a) Food for man
(b) Fodder for animals
(c) As an abrasive ingredient in pastes
(d) A stability agent

184. The reserve food in *Oscillatoria* is stored in the form of:
(a) Starch (b) Glycogen
(c) Fat (d) Protein

185. Which of the following is a prokaryote?
(a) *Cladophora* (b) *Chlamydomonas*
(c) *Oscillatoria* (d) *Spirogyra*

186. *Batrachospermum* is:
(a) Red algae of sea (b) Brown algae
(c) Blue algae (d) Red algae of fresh water

187. Blue-green algae which live endophytically in protozoans are called:
(a) Cyanophages (b) Bacteriophages
(c) Cyanallae (d) Plasmids

188. The giants among algae:
(a) *Microcystis* (b) *Macrocystis*
(c) *Dictyota* (d) *Laminaria*

189. *Ulothrix* is: **(Raj. PMT 1990)**
(a) A colonial alga
(b) Attached and branched filamentous alga
(c) Attached and unbranched filamentous alga
(d) A free floating alga

190. The shape of vegetative cell of *Ulothrix* is:
(a) Round (b) Rectangular
(c) Cylindrical (d) Spherical

191. Flagellated stages are absent in:
(a) *Ulothrix* (b) *Albugo*
(c) *Spirogyra* (d) *Chlamydomonas*

192. When three *Spirogyra* filaments participate in conjugation, then possibilities are that:
(a) The middle one may be female and outer ones are male
(b) The middle one may be male and the outer are female
(c) Both (a) and (b)
(d) None of the above

193. Meiotic division in *Spirogyra* takes place:
(a) In the zygote
(b) During gamete formation
(c) In the tip of germling
(d) During formation of aplanospores

194. The sexual reproduction in which cells of two different *Spirogyra* filaments conjugate is known as: (CPMT 1990)
(a) Lateral conjugation (b) Scalariform conjugation
(c) Parthenospory (d) Azygospory

195. Eye spot or stigma is present in:
(a) *Chlamydomonas* (b) *Spirogyra*
(c) *Ulothrix* (d) *Nostoc*

196. When two mature cells of *Chlamydomonas* fuse together, it is known as:
(a) Autogamy (b) Homogamy
(c) Hologamy (d) Syngamy

197. Which of the following occurs both in fresh water and marine habitat?
(a) *Spirogyra* (b) *Riccia*
(c) *Cladophora* (d) *Oedogonium*

198. *Spirogyra* is so named because:
(a) The chloroplast is spirally arranged
(b) Pyrenoid is spiral
(c) Plasma membrane is spiral
(d) Mitochondria are spiral

199. Fusion of mature individuals which directly act as gametes is called:
(a) Hologamy (b) Autogamy
(c) Heterogamy (d) Conjugation

200. In *Chlamydomonas*, gametes differ from zygospore:
(a) In size (b) In shape of chloroplast
(c) In shape of pyrenoids (d) Can unite

201. In *Spirogyra*, during zygospore germination, out of four haploid nuclei, only:
(a) 1 survives (b) 3 survive
(c) 2 survive (d) All the 4 survive

202. The basal cell of *Ulothrix* is devoid of: (CPMT 1991)
(a) Nucleus (b) Chlorophyll
(c) Chloroplast (d) Pyrenoid

203. What among the following do you consider the best evidence to show that two species of algae are closely related?
(a) They both respire and release CO_2
(b) They both reproduce sexually
(c) They both are found in same type of habitat
(d) They both have same type of pigments

204. *Spirogyra* filaments grow in length by division of its: (AFMC 2001)
(a) Apical cell (b) Basal cell
(c) Rhizoidal cell (d) Every cell of the filament

205. Which of the following attaches itself to substratum by a basal cell known as holdfast?
(a) *Chlamydomonas* (b) *Spirogyra*
(c) *Ulothrix* (d) None of these

206. Which of the following is a colourless parasitic alga? (AMU 1991)
(a) *Chlorella* (b) *Batrachospermum*
(c) *Porphyra* (d) *Harveyella*

207. Product of photosynthesis in blue-green algae generally is:
(a) Glucoside (b) Glycogen-like
(c) Glycerophosphate (d) Globulin

208. Chlorellin is obtained from: (CPMT 1992)
(a) Fungus (b) Algae
(c) Bacteria (d) Cyanobacteria

209. Flagella of zoospores in brown algae are inserted:
(a) Anteriorly (b) Posteriorly
(c) Laterally (d) All round the surface

210. Cyanobacteria is a new name of:
(a) Mycoplasma (b) Blue-green algae
(c) Schizomycetes (d) Myxomycetes

211. The sexual reproduction in *Spirogyra* can be described as:
(a) Morphological anisogamy and physiological isogamy
(b) Morphological as well as physiological isogamy
(c) Morphological as well as physiological anisogamy
(d) Morphological isogamy and physiological anisogamy

212. In *Ulothrix*, meiosis takes place:
(a) In the zygospore
(b) At the time of formation of isogametes
(c) In the zoospores
(d) In the vegetative cells

213. Microzoospores in *Ulothrix* are:
(a) Biflagellate only
(b) Quadriflagellate only
(c) Biflagellate and quadriflagellate
(d) Multiflagellate

214. In eukaryotic algae and fungi, flagella and cilia of zoospores and gametes are:
(a) Generally similar and have $9 + 2$ arrangement of fibrils; the peripheral fibrils are doublets and central fibrils are just canal-like
(b) Have $1 + 0$ arrangement of fibrils
(c) Have $9 + 0$ arrangement of fibrils
(d) The peripheral fibrils are triplets and central are doublets

215. In scalariform conjugation, two fusing gametes of *Spirogyra* are:
(a) Morphologically dissimilar
(b) Morphologically similar but physiologically dissimilar
(c) Morphologically and physiologically dissimilar
(d) Morphologically similar

216. *Ulothrix*, a green alga, is classified among chlorophyceae because of:
(a) Aquatic thalloid habit
(b) Presence of Chlorophyll-a and b
(c) Cellulosic cell wall and starch as food reserve
(d) All of the above

217. The first division of the zygote is meiotic (reduction) in:
(a) Algae (b) Bryophytes
(c) Pteridophytes (d) Gymnosperms

218. All algae have: (CPMT 1990)
(a) Phycobilins and carotene
(b) Chlorophyll-a and chlorophyll-b
(c) Chlorophyll-b and carotene
(d) Chlorophyll-a and carotene

219. During reproduction, the cell of *Chlamydomonas*:
(a) Loses its flagella and becomes non-motile
(b) Loses its flagella and comes to rest
(c) Retains flagella and starts swimming
(d) Retains flagella and starts dividing

220. Pyrenoids are:
(a) Starch surrounded by protein grains
(b) Starch surrounded by oil droplets
(c) Protein surrounded by oil droplets
(d) Protein surrounded by starch grains

221. *Ulothrix* is characterised by:
(a) One chloroplast with several pyrenoids
(b) Several chloroplasts with one pyrenoid
(c) One chloroplast with 2–3 pyrenoids
(d) No chloroplast but 3–8 pyrenoids

222. Algae are a group of plants:
(a) With no chloroplast
(b) Pioneers of the autotrophs
(c) Less pronounced range of sexual reproduction
(d) Very little range of vegetative structure

223. A green plant possessing single-celled reproductive organs, no vascular tissue, and no root, stem or leaf should be classified as:
(a) Algae (b) Fungi
(c) Bryophyte (d) Mycoplasma

224. Fertilization in *Chlamydomonas* is: (CBSE 1990)
(a) Mesogamous (b) Anisogamous
(c) Oogamous (d) Isogamous

225. The product of conjugation of *Spirogyra* is called: (CBSE 1991)
(a) Zoospore (b) Akinete
(c) Chlamydospore (d) Zygospore

226. Trumpet hyphae in certain brown algae resemble:
(a) Tracheids (b) Trachea
(c) Sieve tubes (d) Sclerenchymatous fibres

227. Algae can be described as:
(a) Autotrophic and chemosynthetic
(b) Autotrophic and photosynthetic
(c) Heterotrophic and photosynthetic
(d) Heterotrophic and chemosynthetic

228. In *Spirogyra*:
(a) The filaments showing lateral conjugation are homothallic
(b) The filaments showing lateral conjugation are heterothallic
(c) The filaments showing scalariform conjugation are homothallic
(d) Asexual reproduction occurs by zoospores

229. Which of the following is a parasitic alga? (BHU 2001)
(a) *Oedogonium* (b) *Cephaleuros*
(c) *Sargassum* (d) *Spirogyra*

230. The non-motile, greatly thickened asexual spores are called: (CPMT 1990)
(a) Hypnospores (b) Aplanospores
(c) Macrozoospores (d) Microzoospores

*231. Which is not a characteristic feature in the life history of *Spirogyra*?
(a) Isogamous conjugation (b) Fragmentation
(c) Zoospory (d) None of these

232. Which species of *Ulothrix* is lithophytic?
(a) *U. implexa* (b) *U. flacca*
(c) *U. flaccide* (d) *U. zonata*

233. Fusing gametes in *Ulothrix* are:
(a) Morphologically and physiologically different
(b) Morphologically similar but physiologically different
(c) Morphologically different
(d) Physiologically similar

234. The gametangia and sporangia of *Ulothrix* are:
(a) Jacketed and unicellular
(b) Non-jacketed and unicellular
(c) Jacketed and multicellular
(d) Non-jacketed and multicellular

235. Which one of the following statements concerning the algae is wrong?
(a) Most algae are photosynthetic
(b) Algae can be classified according to their pigments
(c) All algae are filamentous
(d) *Spirogyra* does not produce zoospores

236. Amongst filamentous members of cyanophyceae, the filaments get broken into pieces which slip out and form new colonies. Such pieces are known as:
(a) Hormogonia (b) Heterocyst
(c) Autocolony (d) Autospores

237. Among the following which is obtained from algae?
(a) Agar-agar (b) Chocolate
(c) Butter (d) Wax

238. Female sex organ of Rhodophyceae is termed:
(a) Carpogonium (b) Oogonium
(c) Sporogonium (d) Archegonium

239. The macrozoospores of *Ulothrix* are: (CPMT 1992)
(a) Biciliate (b) Quadriflagellate
(c) Biflagellate (d) None of these

240. In the secretory cells of *Hydra*, there is found a symbiotic alga; it is:
(a) *Zoochlorella* (b) *Nostoc*
(c) *Ulothrix* (d) *Spirogyra*

241. Algae described to be heterotrichous have:
(a) Short and long lateral branches
(b) Short nodal and long internodal cells
(c) Short and long hairs
(d) Prostrate and projecting system developed to a variable length

242. *Spirogyra* differs from *Rhizopus* in having:
(a) Multicellular gametes (b) Sexual reproduction
(c) Anisogametes (d) Uninucleate gametangia

243. *Ulothrix* occurs in:
(a) Warm stagnant water (b) Slow flowing cold water
(c) Warm saline water (d) Slow flowing warm water

244. How many chloroplasts occur in *Ulothrix?*
(a) One, girdle-shaped (b) Two, star-shaped
(c) Three, cup-shaped (d) Many, spiral-shaped

245. The algal component in a lichen generally belongs to the class:
(a) Xanthophyceae (b) Phaeophyceae
(c) Cyanophyceae (d) Rhodophyceae

246. In blue-green algae, process of photosynthesis takes place in:
(a) Lamellae (b) Chromoplasts
(c) Chromatophores (d) Chloroplasts

247. *Chlorella,* a green alga, usually uses the greater amount of energy in:
(a) Mitosis (b) Locomotion
(c) Xanthophyll (d) Chemical reaction

248. Which of the following statements is not true for *Spirogyra* and *Mucor*?
(a) Both have zygotic meiotic division
(b) Both reproduce asexually by spores
(c) Both produce azygospores when asexual reproduction fails
(d) Both produce azygospores and parthenospores

249. Most of the algae which do not have visible nucleus are:
(a) Green algae (b) Blue-green algae
(c) Red algae (d) Phaeophyceae

250. In *Spirogyra,* sometimes the gametes behave directly as zygospores without fusion. Such reproductive bodies are called:
(a) Zygospores (b) Aplanospores
(c) Hypnospores (d) Azygospores

251. Fucoxanthin pigment is found in:
(a) Blue-green algae (b) Green algae
(c) Red algae (d) Brown algae

252. Cell wall of algae is made up of:
(a) Chitin (b) Glycogen
(c) Cellulose (d) Muramic acid

*253. Three kinds of zoospores have been reported in:
(a) *Ulothrix* (b) *Chara*
(c) *Oedogonium zonata* (d) *Ulothrix zonata*

254. *Anabaena* occurs in the cavities of:
(a) *Laminaria* (b) *Azolla,* a water fern
(c) *Marsillea* (d) None of these

255. Incipient sporophyte is observed in the life cycle of:
(a) *Oedogonium* (b) *Ulothrix*
(c) Both (a) and (b) (d) None of these

256. A general blue-green or olive-green colouration of the plant body in case of members of cyanophyceae is due to the presence of pigment:
(a) Carotenoid (b) Phycocyanin
(c) Chlorophyll (d) All of these

257. Certain cyanophyceae are associated with the fungi in the formation of:
(a) Gymnosperms (b) Lichens
(c) Xerophytes (d) Bryophytes

258. Most advanced and evolved type of thallus met within chlorophyceae is:
(a) Branched filament (b) Foliaceous thallus
(c) Colonial thallus (d) Heterotrichous filament

259. Juvenile stage in red algae is known as:
(a) Sporophyte (b) Protonema
(c) Chantransia stage (d) None of these

260. Dwarf male plants or nannandria are observed in:
(a) *Volvox* (b) *Chlamydomonas*
(c) *Cosmarium* (d) *Oedogonium*

261. Heterocysts are not observed in:
(a) Diatoms (b) Oscillatoriaceae
(c) Chlorophyceae (d) All of these

262. A single row of cells in a filamentous colony of cyanophyceae is known as:
(a) Trichome (b) Cyst
(c) Filament (d) Rhizoid

263. "Amanori" bread is prepared from the:
(a) *Alaria* (b) *Codium*
(c) *Porphyra* (d) *Chondrus*

264. The product of isogamy is known as:
(a) Oospore (b) Hypnospore
(c) Zygospore (d) Zoospore

265. The percentage of protein in *Chlorella* is:
(a) 27% (b) 75%
(c) 50% (d) 40%

266. A typical prokaryotic cell is found in:
(a) *Aspergillus* (b) *Nostoc*
(c) *Pteris* (d) *Ulothrix*

*267. 'Khombu' is the common name of an edible alga called:
(a) *Durvillea* (b) *Ulva*
(c) *Laminaria* (d) *Porphyra*

268. Blue-green algae belong to: **(CBSE 1996)**
(a) Eukaryotes (b) Rhodophyceae
(c) Prokaryotes (d) Chlorophyceae

269. Agar-2, a complex carbohydrate, is extracted from: **(AFMC 1996; CPMT 1999)**
(a) Blue-green algae (b) Brown algae
(c) Green algae (d) Red algae

270. The cell wall of *Spirogyra* is made up of: **(MPPMT 1996)**
(a) Cellulose (b) Pectin
(c) Lignin (d) Chitin

271. The characteristic pigment of cyanobacteria is: **(MPPMT 1996)**
(a) Fucoxanthin (b) Chlorophyll-b
(c) Anthocyanin (d) Phycocyanin

272. Dinitrogen fixation by *Nostoc* takes place in: **(MPPMT 1996)**
(a) Vegetative cells (b) Akinetes
(c) Heterocysts (d) Hormogonia

273. Heterocysts are found in certain: **(MPPMT 1997)**
(a) Viruses (b) Bacteria
(c) Cyanobacteria (d) Mycoplasmas

274, Genetic recombination in blue-green algae was discovered by:
(a) H.D. Kumar (b) Desikachary
(c) M.O.P. Iyenger (d) Y. Bhardwaj

275. Which of the following is the largest alga?
(a) *Nereocystis* (b) *Laminaria*
(c) *Macrocystis* (d) *Sargassum*

276. 'Palmella' stage is characteristic of: (BHU 2002)
(a) *Chlamydomonas* (b) *Ulothrix*
(c) Both (a) and (b) (d) None of these

277. A spore of *Spirogyra* sps. after resting period is: (MPPMT 1997)
(a) Haploid (b) Diploid
(c) Aplanospore (d) Zygospore

278. *Chlorella* yields an antibiotic:
(a) Fuscin (b) Pectin
(c) Chlorellin (d) None of these

279. Which of the following algae has been studied in space?
(a) *Chara* (b) *Spirogyra*
(c) *Ulva* (d) *Chlorella*

280. Important feature of *Spirogyra* that distinguishes it from *Ulothrix* is:
(a) Its habitat (b) Its size of vacuole
(c) The structure of nucleus (d) Its slimy nature

281. In *Ulothrix* a single cell may produce gametes ranging between:
(a) 4–16 (b) 0–32
(c) 8–64 (d) 8–32

282. In green algae pyrenoid is surrounded by:
(a) Ribosomes (b) Starch grains
(c) Amino acids (d) Nucleic acids

283. The diatoms do not readily decay like most other algae because:
(a) They are non-living cells
(b) They have water-proof cell walls
(c) They have highly siliceous walls
(d) They have a mucilaginous wall

*284. Iodine can be extracted from:
(a) *Ulva* (b) *Ceramium*
(c) *Vaucheria* (d) *Fucus*

285. The alga showing dimorphic branching is:
(a) *Ectocarpus* (b) *Scytonema*
(c) *Cladophora* (d) *Batrachospermum*

286. Carrageenin is obtained from: (BHU 2002)
(a) *Batrachospermum* (b) *Chondrus*
(c) *Sargassum* (d) *Ulva*

287. Alga used for the construction of sound-proof room is:
(a) *Ulva* (b) *Volvox*
(c) Diatoms (d) *Chara*

288. How many plants are produced from a zygospore of *Ulothrix?*
(a) 16–34 (b) 1–12
(c) 4–16 (d) 3–16

289. Fertilization in *Spirogyra* occurs in:
(a) The cell which produces active gamete
(b) Water
(c) The cell which produces passive gamete
(d) Conjugation canal

290. Synzoospore is found in:
(a) *Porphyra* (b) *Vaucheria*
(c) *Sargassum* (d) *Ulva*

291. *Oscillatoria* is a member of:
(a) Chlorophyta (b) Phaeophyta
(c) Cyanophyta (d) Rhodophyta

292. Which of the following is found in blue-green algae?
(a) Starch (b) Any polysaccharide
(c) Floridean starch (d) Cyanophycin granules

293. *Ulothrix* utilises greatest amount of energy in:
(a) Mitosis (b) Absorption
(c) Adaptation (d) Digestion

294. The ratio of length to breadth in *Ulothrix* cell is:
(a) Three (b) One
(c) Less than one (d) More than one

295. *Spirogyra* is commonly known as pond silk because:
(a) It is slimy to touch
(b) Silk is manufactured from it
(c) It looks like silk thread
(d) All of the above

296. Algae found growing attached to bottom soil are called as:
(a) Epipelic (b) Epilithic
(c) Benthos (d) Sciophyte

297. Mark the parasitic alga:
(a) *Anabaena* (b) *Ulva*
(c) *Ulothrix* (d) *Cephaleuros*

*298. Gas vacuoles occur in the cells of:
(a) Brown algae (b) Blue-green algae
(c) Red algae (d) Green algae

299. Some algae grow on snow, giving the snow decidedly a:
(a) Pinkish colour (b) Green colour
(c) Brown colour (d) Yellow colour

300. Chief phytoplanktons are:
(a) Dinoflagellates
(b) Diatoms
(c) Bacteria and protozoans
(d) Diatoms and dinoflagellates

301. Which one of the following algae is endozoic?
(a) *Ulva* (b) *Zoochlorella*
(c) *Volvox* (d) *Polysiphonia*

302. Which of the following algae is leaf-like and known as sea-lettuce?
(a) *Nostoc* (b) *Ulva*
(c) *Ulothrix* (d) *Spirogyra*

303. The members of chlorophyceae are:
(a) Rarely terrestrial (b) Mostly aquatic
(c) Both (a) and (b) (d) None of these

304. Algae grow:
(a) On damp soil (b) In water
(c) As epiphytes (d) All of these

305. The zygospore of *Spirogyra* produces:
(a) 2–4 zoospores (b) 4 zoospores
(c) 2 zoospores (d) None of these

306. Which one of the following is a larvicidal alga?
(a) *Euglena* (b) *Pandorina*
(c) *Oscillatoria* (d) *Polysiphonia*

307. Meiosis in *Chlamydomonas* occurs in: (Pb. PMT 1997)
(a) Zygospore (b) Zoospore
(c) Aplanospore (d) Hypnospore

308. The cell wall of *Spirogyra* is made up of: (MPPMT 1996)
(a) Cellulose (b) Pectin
(c) Lignin (d) Chitin

309. An alga very rich in proteins is: (CBSE 1997)
(a) *Spirogyra* (b) *Ulothrix*
(c) *Oscillatoria* (d) *Chlorella*

310. The nitrogen fixation by *Nostoc* takes place in: (MPPMT 1996)
(a) Vegetative cells (b) Akinetes
(c) Heterocysts (d) Hormogonia

311. Brown algae are characterised by the presence of: (CBSE 1997)
(a) Phycocyanin (b) Phycoerythrin
(c) Fucoxanthin (d) Haematochrome

312. Which of the following is a parasite on tea plant? (BHU 1996, 97)
(a) *Cephaleuros* (b) *Nostoc*
(c) *Striga* (d) *Loranthus*

313. Which algae occurs in still fresh water? (CET Chandigarh 1997)
(a) *Spirogyra* (b) *Laminaria*
(c) *Sargassum* (d) *Polysiphonia*

314. The yield of paddy can be increased by the application of: (MPPMT 1997; CET Chandigarh 1997)
(a) *Nostoc* (b) Symbiotic bacteria
(c) Iron bacteria (d) Archaebacteria

315. Unicellular cyanobacteria reproduce asexually by: (AIIMS 1994)
(a) Conjugation (b) Fragmentation
(c) Binary fission (d) Hormogones

316. Which of the following has a coenocytic thallus? (BHU 1996; Pondicherry 1997)
(a) *Spirogyra* (b) *Chlamydomonas*
(c) *Vaucheria* (d) *Nostoc*

317. Blue-green algae associated with red tide phenomenon is:
Or
Red tides are caused by: (BHU 1996; CET Chandigarh 1997)
(a) *Anabaena* (b) *Nostoc*
(c) *Gleocapsa* (d) *Trichodesmium*

318. Green wavelength of sunlight is absorbed by: (BHU 1994)
(a) Phycoerythrin (b) Carotenoids
(c) Chlorophyll (d) Phycocyanin

319. During monsoon ground becomes slippery because of: (Pondicherry 1997)
(a) Green algae (b) Blue-green algae
(c) Mosses (d) Liverworts

320. Algae possess photosynthetic pigments and hence they are called as: (AMU 1997; Manipal 1997)
(a) Parasitic (b) Holophytic
(c) Saprophytic (d) Holozoic

321. Agar is obtained from: (AFMC 1997)
(a) *Gelidium* (b) *Rhizopus*
(c) *Chlorella* (d) *Batrachospermum*

322. Which blue-green alga remains in symbiotic association with *Anthoceros*? (CPMT 1997)
(a) *Azolla* (b) *Spirochaete*
(c) *Spirulina* (d) *Nostoc*

323. Fucoxanthin accessory pigment occurs in: (CPMT 1997; Raj. PMT 2001)
(a) Brown algae (b) Red algae
(c) Blue-green algae (d) Green algae

324. In *Spirogyra* meiotic division occurs in: (CPMT 1997)
(a) Zygospore (b) Zoospore
(c) Pollen grain (d) Egg

325. The thermal algae can survive in a hot water spring at: (BHU 1997)
(a) 60°C (b) 70°C (c) 80°C (d) 90°C

326. Parasitic alga is: (BHU 1997)
(a) *Volvox* (b) *Vaucheria*
(c) *Cephaleuros* (d) *Oedogonium*

327. *Protoderma* in alga is:
(a) Epizoic (b) Endozoic
(c) Epiphytic (d) Parasitic

328. The characteristic pigment of cyanobacteria is: (MPPMT 1996, 97)
(a) Fucoxanthin (b) Cell
(c) Anthocyanin (d) Phycocyanin

329. Calcium encrustation and larvicidal properties are present in: (AMU 1997)
(a) *Chara* (b) *Oscillatoria*
(c) Diatoms (d) *Caulerpa*

330. *Ulothrix* filaments produce: (CBSE 1997)
(a) Isogametes (b) Anisogametes
(c) Heterogametes (d) Basidiospores

331. Ancestor of land plants had: (Pb. PMT 1997)
(a) Prostrate habit (b) Heterotrichous habit
(c) Thorny habit (d) Arboreal habit

332. Oil is the reserve food in: (BHU 1997)
(a) *Chlamydomonas* (Chlorophyceae)
(b) *Vaucheria* (Xanthophyceae)
(c) *Nostoc* (Myxophyceae)
(d) *Sargassum* (Phaeophyceae)

333. Which of the following helps in N_2-fixation? (CPMT 1998)
(a) *Albugo* (b) *Nostoc*
(c) *Penicillium* (d) *Puccinia*

334. Agar-agar is obtained from: [CPMT 1998; BCECE (P.T. Exam.) 2002]
(a) *Chlorella* (b) *Chara*
(c) *Gelidium* (d) *Laminaria*

335. Alga associated with *Cycas* root is: (CPMT 1998)
(a) *Anabaena* (b) *Chara*
(c) *Chlorella* (d) *Cladophora*

336. *Ulothrix* can be described as a: (CBSE 1998)
(a) Filamentous alga with flagellated reproductive stages
(b) Non-motile colonial alga lacking zoospores
(c) Filamentous alga lacking flagellated reproductive stages
(d) Membranous alga producing zoospores

337. The food is stored in the form of oil in: (CPMT 1998)
(a) Chlorophyceae (b) Rhodophyceae
(c) Xanthophyceae (d) Cyanophyceae

338. Some micro-organisms forming nuisance water blooms in lakes, ponds, oceans belong to: (CBSE 1999)
(a) Brown and red algae
(b) Desmids and myxomycetes
(c) Cyanobacteria and dinoflagellates
(d) Aquatic angiosperms and algal fungi

*339. Which type of ribosomes are found in *Nostoc* cells? (MPPMT 1999)
(a) 50S (b) 60S
(c) 70S (d) Eukaryotic

*340. *Spirogyra* has a: (MPPMT 1999)
(a) Haplontic life cycle (b) Diplontic life cycle
(c) Haplobiontic life cycle (d) Diplobiontic life cycle

341. An alga contains chlorophyll-a, chlorophyll-d and phycoerythrin. It belongs to : (CBSE 2000)
(a) Bacillariophyceae (b) Rhodophyceae
(c) Phaeophyceae (d) Cyanophyceae

*342. Element present in thyroxine can be obtained from: (CPMT 2000)
(a) *Polysiphonia* (b) *Chara*
(c) *Laminaria* (d) *Spirogyra*

343. Teichoic acid is present in cell wall of: (MPPMT 2000)
(a) Bacteriophage (b) Mycoplasma
(c) *Nostoc* (d) Virus

344. *Nostoc* is a: (MPPMT 2000)
(a) Green alga (b) Yellow-green alga
(c) Blue-green alga (d) Red alga

345. In *Ulothrix*, zygote is: (Uttaranchal PMT 2001)
(a) Aflagellated (b) Uniflagellated
(c) Biflagellated (d) Multiflagellated

346. Sexual reproduction in *Spirogyra* is by: (Uttaranchal PMT 2001)
(a) Fragmentation (b) Conjugation
(c) Physiological isogamy (d) Oogamy

347. Which of the following is found in ponds, has a slimy nature and forms a scum over ponds? (Manipal 2001)
(a) *Chlamydomonas* (b) *Oscillatoria*
(c) *Spirogyra* (d) *Nostoc*

348. Which of the following is correct regarding diatoms? (Manipal 2001)
(a) Have sculptured cell wall made of silica
(b) Have U-shaped chloroplast
(c) Generally motile and multicellular
(d) None of the above

*349. Which of the following depicts the characteristic of both plants and animals? (AIIMS 2001)
(a) *Volvox* (b) *Paramecium*
(c) *Monocystis* (d) *Entamoeba*

350. Zygospore of *Spirogyra* at the time of meiosis is divided into 4 nuclei. How many nuclei degenerate out of these four? (AIIMS 2001)
(a) One (b) Two
(c) Three (d) Four

351. Diatomaceous earth is formed due to remains of which part of diatoms? (BHU 2001)
(a) Cell wall (b) Chloroplast
(c) Cytoplasm (d) Skeleton masses

352. Stomata are not found in: (MPPMT 2001)
(a) Algae (b) Mosses
(c) Ferns (d) Liverworts

*353. Marine algae flourished well during which of the following period? (CPMT 2002)
(a) Ordovician (b) Devonian
(c) Permian (d) Triassic

354. Cell wall of *Chlamydomonas* contains: (CET J&K 2002)
(a) Cellulose (b) Glycoproteins
(c) Protein (d) Hemicellulose

355. Nitrogen fixers in *Azolla* are: (CET J&K 2002)
(a) *Nostoc* (b) *Anabaena*
(c) *Aulosira* (d) *Azospirillum*

*356. Which of the following algae can be used as bacteriological filter? (JIPMER 2002)
(a) *Batrachospermum* (b) *Gelidium*
(c) *Oscillatoria* (d) *Cymbella*

357. Life cycle of *Ulothrix* is: (Raj. PMT 2001; MPPMT 2002)
(a) Haplobiontic (b) Diplobiontic
(c) Haplodiplobiontic (d) None of these

358. Blue-green algae are found in: (Raj. PMT 2001)
(a) *Riccia* (b) *Pinus* root
(c) *Cycas* root (d) Scales of *Marchantia*

359. Algae are useful because they: (AIIMS 2002)
(a) Are large in number
(b) Purify the atmosphere
(c) Are used in alcoholic fermentation
(d) Are used in study of photosynthesis

360. Algae used by Calvin *et al.* is: (St. Jones 2002; Raj. PMT 2002)
(a) *Chlorella* (b) *Chlamydomonas*
(c) *Euglena* (d) *Chara*

361. Which one of the following is also algae? (MPPMT 2002)
(a) Cyanobacteria (b) *Rhodospirillum*
(c) Green bacteria (d) Purple bacteria

362. In *Spirogyra*, a brief period of tetranucleate condition is found in: (EAMCET 2002)
(a) Holdfast (b) Gametangium
(c) Vegetative cell (d) Germinating zygote

363. Pigments present in chloroplast of *Ulothrix* are: (Raj. PMT 2002)
(a) Chlorophyll-a, Chl-b, fucoxanthin, β-carotene
(b) Chl-a, Chl-b, Chl-c, C-phycocyanin, C-phycoerythrin
(c) Chl-a, Chl-b, β-carotene, xanthophyll
(d) Chl-a, Chl-b, r-phycocyanin, r-phycoerythrin

364. The red colour in red algae is due to: (Orissa JEE 2003)
(a) Haemoglobin (b) Anthocyanin
(c) Phycoerythrin (d) Carotene

365. Chloroplasts of *Spirogyra* have: (B.V. Pune 2003)
(a) Wavy margin (b) Smooth or wavy margin
(c) Smooth margin (d) None of these

366. People recovering from long illness are often advised to include the alga *Spirulina* in their diet because it: (AIIMS 2003)
(a) Makes the food easy to digest
(b) Is rich in proteins
(c) Has antibiotic properties
(d) Restores the intestinal microflora

ANSWERS

1—c	2—c	3—a	4—b	5—d	6—d	7—b	8—c	9—d	10—c	11—d	12—c
13—b	14—d	15—d	16—d	17—b	18—c	19—c	20—c	21—c	22—a	23—c	24—c
25—c	26—b	27—b	28—a	29—b	30—d	31—d	32—d	33—c	34—d	35—c	36—b
37—b	38—b	39—b	40—d	41—b	42—d	43—b	44—c	45—b	46—d	47—c	48—d
49—a	50—c	51—a	52—a	53—d	54—d	55—a	56—b	57—b	58—b	59—b	60—c
61—b	62—a	63—a	64—c	65—a	66—b	67—c	68—c	69—c	70—a	71—d	72—a
73—c	74—c	75—a	76—b	77—b	78—d	79—d	80—b	81—b	82—c	83—a	84—d
85—c	86—c	87—b	88—c	89—d	90—d	91—b	92—b	93—a	94—b	95—d	96—a
97—a	98—d	99—c	100—d	101—c	102—a	103—d	104—a	105—a	106—a	107—a	108—c
109—a	110—a	111—c	112—b	113—a	114—a	115—c	116—c	117—c	118—c	119—b	120—c
121—b	122—a	123—b	124—d	125—c	126—a	127—a	128—a	129—c	130—a	131—d	132—a
133—b	134—c	135—a	136—b	137—c	138—b	139—b	140—c	141—b	142—b	143—c	144—b
145—c	146—c	147—c	148—d	149—b	150—c	151—b	152—b	153—c	154—c	155—c	156—d
157—b	158—a	159—d	160—c	161—b	162—b	163—b	164—d	165—a	166—c	167—c	168—c
169—d	170—c	171—d	172—c	173—c	174—d	175—c	176—a	177—d	178—d	179—c	180—d
181—d	182—d	183—d	184—b	185—c	186—d	187—c	188—b	189—c	190—b	191—c	192—c
193—a	194—b	195—a	196—c	197—c	198—a	199—a	200—d	201—a	202—b	203—d	204—d
205—c	206—d	207—b	208—b	209—c	210—b	211—d	212—a	213—c	214—a	215—b	216—d
217—a	218—d	219—b	220—d	221—a	222—b	223—a	224—d	225—d	226—c	227—b	228—a
229—b	230—a	231—c	232—a	233—b	234—b	235—c	236—a	237—a	238—a	239—b	240—a
241—d	242—d	243—b	244—a	245—c	246—a	247—a	248—b	249—b	250—d	251—d	252—c
253—d	254—b	255—c	256—d	257—b	258—d	259—c	260—d	261—d	262—a	263—c	264—c
265—c	266—b	267—c	268—c	269—d	270—a	271—d	272—c	273—c	274—a	275—a	276—c
277—a	278—c	279—d	280—d	281—c	282—b	283—c	284—d	285—d	286—b	287—c	288—c
289—c	290—b	291—c	292—d	293—a	294—c	295—a	296—b	297—d	298—b	299—a	300—d
301—b	302—b	303—c	304—d	305—d	306—c	307—a	308—a	309—d	310—c	311—c	312—a
313—a	314—a	315—c	316—c	317—d	318—a	319—b	320—b	321—a	322—a	323—a	324—a
325—b	326—a	327—a	328—d	329—a	330—a	331—d	332—b	333—b	334—c	335—a	336—a
337—c	338—c	339—c	340—a	341—b	342—c	343—c	344—c	345—d	346—b	347—b	348—a
349—a	350—c	351—a	352—a	353—a	354—a	355—b	356—d	357—a	358—c	359—b	360—a
361—a	362—d	363—c	364—c	365—a	366—b						

EXPLANATION OF SELECTED QUESTIONS (*)

40. Sewage oxidation ponds have luxuriant growth of algae (like *Chlorella, Scenedesmus, Chlamydomonas*, etc.) and aerobic bacteria.
50. Silicified cell walls (having silicon dioxide) are found in diatoms or members of class bacillariophyceae of algae.
55. r-phycoerythrin and r-phycocyanin (present in red algae) absorb the blue-green region (480–520 nm) of spectrum.
62. Heterocysts are characteristic of blue-green algae and probably help in N_2-fixation.
68. Different species of *Chlamydomonas* show all three types of sexual reproduction, *i.e.*, isogamy, anisogamy and oogamy.
105. Carotenoid pigments are present in eye spot or stigma.
115. Hormogonia (segments of trichomes) are formed in blue-green algae.
153. Red oceanic tides are caused due to *Gonyaulax* (a member of class dinophyceae) as it has property of bioluminescence.
231. There is no flagellate phase in life cycle of *Spirogyra*.
253. Most common fresh water sps. of *Ulothrix*, *i.e.*, *U. zonata* produces three kinds of zoospores, *i.e.*, biflagellated and tetraflagellated microzoospores as well as tetraflagellated macrozoospores.
267. 'Khombu' is a diet of Japan and it is prepared from *Laminaria* species.
284. Iodine is extracted from brown algae like *Laminaria, Fucus, Ascophyllum*, etc.
298. Gas vacuoles are found in most of the blue-green algae which help in buoyancy.
339. *Nostoc* is prokaryotic (blue-green alga) and hence 70S type of ribosomes are present.
340. Life cycle in *Chlamydomonas, Ulothrix* and *Spirogyra* is haplontic as dominant phase in life is haploid and diploid phase is represented only by zygote or zygospore.
342. Iodine is present in thyroxine hormone of thyroid gland and iodine is obtained from brown algae.
349. *Volvox globator* and *Volvox aureus* are colonial flagellates, which are having cellulosic cell wall and starch as reserve food material.
353. Marine algae flourished well during ordovician period of palaeozoic era.
356. *Cymbella* is a diatom and the diatoms trap and conserve the bacteria.

11

Fungi and Lichens

- Fungi: General introduction, Similarities of fungi with algae, Differences between algae and fungi, Famous mycologists, Habitat of fungi, Structure of fungi, Classification of fungi, Some common names of fungi, Reproduction in fungi, Economic importance of fungi
- Life cycle of Rhizopus, Heterothallism
- Life cycle of Yeast, economic importance of yeasts
- Characteristic features of some other important fungi: *Albugo, Puccinia, Agaricus*
- Lichens: General introduction, Habitat, Classification of lichens, Some special structures associated with lichen thallus, Reproduction in lichens, Economic importance of lichens

FUNGI

(Singular—Fungus)

The term 'fungus' has been derived from the Latin word which means **mushroom.**

- Fungi constitute the largest sub-group of **thallophyta** which is having about 1 lakh species. Fungi are **eukaryotic organisms** which feed on dead or decaying organic matter or parasitize living organisms. Most of the fungi are ecologically important **decomposers,** some are important in the production of food and some fungi cause diseases in plants and animals.
- Fungi are, "Achlorophyllous, spore bearing, non-vascular organisms or plants, which reproduce both sexually and asexually and whose generally filamentous and much branched plant body (mycelium) is surrounded by cell wall made of **chitin or fungus cellulose or both.**"
- Fungi include many forms like **moulds, mushrooms, toad stools, rusts, smuts, puffballs, pore fungi, mildews,** etc.
- Alexopoulos and Mims placed fungi in a separate **kingdom,** *i.e.*, **Myceteae** and hence the study of fungi is known as **Mycetology.** Ainsworth placed all fungi in kingdom **Mycota.**

Further, this branch is also known as Mycology (Greek word; *Mykes* means **mushroom**).

Similarities of fungi with algae

1. Both are moisture loving.
2. In both the plant body is thallose, *i.e.*, no differentiation into root, stem and leaves.
3. Both are **non-vascular,** *i.e.*, xylem and phloem absent.
4. In both sex organs are **unicellular** and **non-jacketed.**
5. No embryo formation in life cycle.
6. Asexual reproduction occurs by **mitospores.**

Differences between algae and fungi

Algae	Fungi
1. Mostly aquatic and found in well-exposed or light conditions.	They are moisture loving but mostly terrestrial and found in dark and moist conditions.
2. Chlorophyll is present.	Absent.
3. Autotrophic in their mode of nutrition.	Heterotrophic in their mode of nutrition. Further, they may be **parasitic or saprophytic.**
4. Cell wall is made up of **cellulose.**	Cell wall is made up of **fungus cellulose or chitin.**
5. Reserve food material in algae is starch or oil globules (glycogen is absent).	Glycogen is reserve food material.
6. True parenchyma is present, formed by cell division.	Pseudoparenchyma is present, which is formed by interwoven mycelium.
7. As we move from lower forms to higher forms (**Myxophyceae to Rhodophyceae**), there is progressive elaboration of sex organs or sexual reproduction.	As we move from lower to higher forms (**Phycomycetes to Deuteromycetes**), there is reduction in sexuality and in Deuteromycetes sexual reproduction is completely absent and hence is known as **imperfect fungi.**

Famous mycetologists or mycologists

The workers involved in fungal studies are called **mycologists** or **mycetologists.** Some mycologists of **International** fame are:

Pliny, Clausius, Tournefort Joseph, Dillenius, Pier Antonio Micheli, Needham (gave spontaneous creation theory), Kasper Bauhin, Anton de Bary, Blakeslee, Bessey, Magnus, Corda, Muller, Buller, Alexopoulos, Mims, Ainsworth, Martin, etc.

- ○ **P. Antonio Micheli** (Italian) gave accurate descriptions and illustrations of fungi in his book *'Nova Plantarum Genera'* and he is rightly called **'Father of Mycology'.**
- ○ **Anton de Bary** is known as **'Father of Modern Mycology and Plant Pathology'.**

Famous Indian mycologists

- ○ **E.J. Butler** (1920) started studies on fungi and diseases caused by them in Pusa Institute (Bihar) and he is known as **'Father of Indian Mycology and Plant Pathology.'**
- Besides, **Dastur, Mundkar, Prof. K.C. Mehta** (associated with study of annual recurrence of wheat rust in India), **Thind, Srinivasan, K.G. Mukherji, Chaudhary** and **Sadasivan** are other famous mycologists of India.

Habitat of fungi

Fungi occur in a variety of habitats, *i.e.,* **ubiquitous.**

- Most of them are moisture loving and terrestrial, but a few are **aquatic,** *e.g., Monoblepharis* and *Saprolegnia* and these are commonly known as **'water moulds'.** (*Saprolegnia* is present on dead flies in water).
- As fungi are **heterotrophic** in their mode of nutrition, so they are saprophytic or parasitic.

Saprophytic fungi are those which grow on dead organic matter, *e.g., Mucor* on **horse dung** and *Pilobolus* on **dung (coprophillous fungi).**

- *Rhizopus* (pin mould or black mould) grows on bread and hence also called **bread mould.**
- *Penicillium* (blue mould) grows on fruits (specially *Citrus*) and also on jams, jellies and pickles.

Epiphytic fungi: A few fungi are epiphytic, *e.g., Armillaria* on apple tree and causes red rot of apple.

Symbiotic fungi: In **lichens,** some members of ascomycetes and basidiomycetes class live in symbiotic association with algae and form **lichen thalli.**

Mycorrhiza: (*Mykes* - fungus + *rhiza* - roots): It is association of fungi with roots of higher plants. It may be **ectotrophic,** *e.g., Pinus* or **endotrophic,** *e.g.,* Orchids.

- ○ (*Rhizoctonia* is a common fungus associated with roots of orchids.)

Predacious fungi: There are some soil fungi which live upon annelids, eelworms, nematodes and rotifers, etc.,found in soil. These fungi have rings in their mycelium which act as nooses and in these nooses worms are trapped and killed.

- Important predacious fungi are: *Dactyllela, Dactylaria, Arthrobotrys* and *Zoophagus,* etc.

Parasitic fungi: They obtain their food from living hosts. These may be:

- (a) **Ectophytic:** These are outside, *e.g., Erysiphe* (Powdery mildew).
- (b) **Endophytic:** These are inside the tissue of plants, *e.g., Albugo, Phytophthora, Alternaria.*

- ○ Fungi grow well at **20–30°C** and at **acidic pH (6.0).**

Structure of fungi

Fungi range from unicellular, uninucleate forms like yeast and *Synchytrium* to much branched filamentous thread-like forms (mycelium).

- Mycelium is made of units called **hyphae** (Greek word *Hypha* means web).
- Hyphae show **apical growth.**
- The hyphae may be **aseptate** and multinucleate (coenocytic); however, in reproductive phase, septa may be formed, *e.g., Rhizopus, Albugo, Phytophthora,* etc.,or may be **septate.** In septate forms, each cell may be uninucleate (monokaryotic) or dikaryotic or with many nuclei.

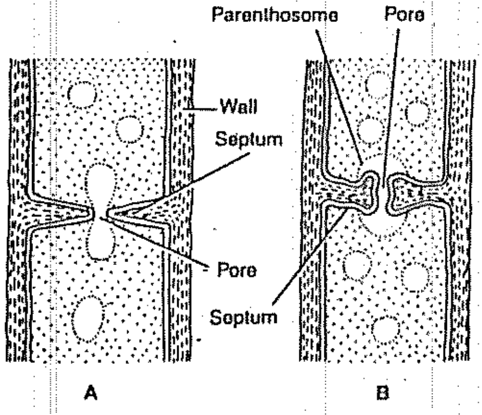


Fig. 11.1. A. Septum with simple pore
B. Septum with dolipore

- The septum may be with **simple pore** or with **dolipore** (in some Basidiomycetes).
- In some **slime-moulds** or myxomycetes, cell wall may be absent but in most of the cases, definite cell wall is present in hyphae which is made of **chitin** (a polymer of N-acetyl glucosamine) or **fungal cellulose.** Inside cell wall is cell membrane, followed by protoplasm having usual cell organelles like E.R., mitochondria, dictyosomes, etc.,and also some non-living inclusions like glycogen granules and lipid granules, etc.
- The mycelium may form some peculiar structures in some fungi like:

1. Plectenchyma

When mycelium is interwoven to form web like structure. It is of 2 types:

- (i) **Prosoplectenchyma:** When mycelium forms web in which individual hyphae are distinguished.
- (ii) **Pseudoparenchyma:** When web is so compact that we cannot distinguish individual hyphae.

2. Sclerotia

When mycelium by interweaving forms compact resting structure, it is called **sclerotium.**

- In sclerotium, in the centre is prosoplectenchyma which is surrounded on all sides by pseudoparenchyma, *e.g.*, in *Claviceps purpurea* (which causes ergot disease of bajra).

3. Rhizomorphs

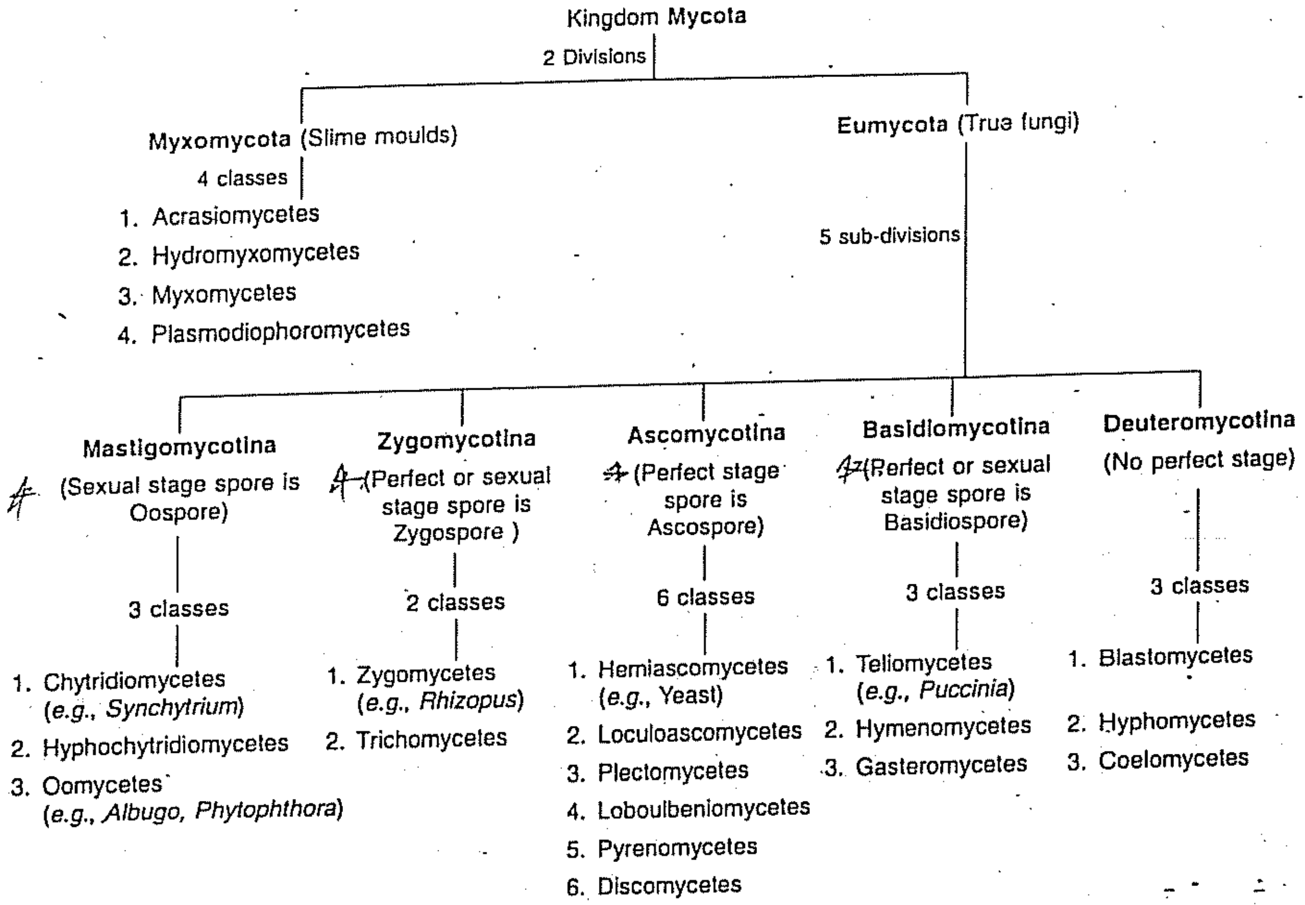
Sometimes fungal mycelia are interwoven to form thick cord-like structures like roots, which are known as rhizomorphs and they function like roots, *i.e.*, help in absorption, *e.g.*, in *Agaricus*.

Classification of fungi

Different classifications of fungi have been given from time to time by different workers like **Martin** (1955), **C.I. Alexopoulos** (1962, 66) and **Ainsworth** (1966, 73).

Ainsworth's classification

It is more natural system. He included all fungi in kingdom-Mycota. The outline classification is:


Kingdom Mycota
2 Divisions
Myxomycota (Slime moulds)
4 classes
1. Acrasiomycetes
2. Hydromyxomycetes
3. Myxomycetes
4. Plasmodiophoromycetes
Eumycota (True fungi)
5 sub-divisions
Mastigomycotina
4
(Sexual stage spore is Oospore)
3 classes
1. Chytridiomycetes (e.g., Synchytrium)
2. Hyphochytridiomycetes
3. Oomycetes (e.g., Albugo, Phytophthora)
Zygomycotina
4
(Perfect or sexual stage spore is Zygospore)
2 classes
1. Zygomycetes (e.g., Rhizopus)
2. Trichomycetes
Ascomycotina
4
(Perfect stage spore is Ascospore)
6 classes
1. Hemiascomycetes (e.g., Yeast)
2. Loculoascomycetes
3. Plectomycetes
4. Loboulbeniomycetes
5. Pyrenomycetes
6. Discomycetes
Basidiomycotina
4
(Perfect or sexual stage spore is Basidiospore)
3 classes
1. Teliomycetes (e.g., Puccinia)
2. Hymenomycetes
3. Gasteromycetes
Deuteromycotina
(No perfect stage)
3 classes
1. Blastomycetes
2. Hyphomycetes
3. Coelomycetes

- Traditionally fungi are divided into 6 classes as follows:

1. **Schizomycetes** (Bacteria).

2. **Myxomycetes** (Slime moulds): Plant body is naked, amoeboid, multinucleate; protoplast often called **pseudoplasmodium,** *e.g., Physarum, Stemonitis,* etc.

3. **Phycomycetes** (Algal fungi):

(i) Somatic phase consists of either unicellular thallus or a non-septate coenocytic mycelium. The septa usually remain suppressed in actively growing stage.

(ii) Asexual reproduction takes place by sporangiospores and sometimes by **conidia.** Sporangiospores **motile** in aquatic species and **non-motile** in terrestrial species.

(iii) No complex fructification.

(iv) Sexual reproduction is isogamous or heterogamous. *Saprolegnia, Monoblepharis, e.g., Rhizopus, Mucor* (black moulds), (Water moulds), *Phytophthora, Pythium, Peronospora, Albugo,* etc.

4. Ascomycetes (Sac fungi):
   - (i) Somatic phase consists of a well developed, branched septate mycelium. Simple pores in the septum.
   - (ii) Hyphal fusion between neighbouring hyphae are frequent.
   - (iii) Characteristic spores of perfect stage are ascospores, which are endogenous in origin.
   - (iv) Ascospores are produced in small, thin-walled sac-like units called **asci** (Singular ascus).
   - (v) Ascus has definite number of ascospores (usually 8).
   - (vi) Ascus is a product of sexual reproduction (explosive sporangium).
   - (vii) There is short **dikaryophase**, which is parasitic on haplophase and occurs within the sexual fruiting bodies.
   - (viii) Complete **absence of motile cells.**
   - (ix) Asexual reproduction occurs by non-motile exogenously produced spores, called **conidia** on conidiophores.
   - (x) The asci in most cases are grouped to form definite fruiting bodies called **ascocarps.**

Ascocarp —
- Apothecium (Cup-shaped)
- Perithecium (Flask-shaped)
- Cleistothecium (Globose, without opening)

   - (xi) Crozier formation occurs in formation of ascus.

e.g., Yeast, *Penicillium*, *Aspergillus*, *Neurospora*, *Erysiphe* (powdery mildew), *Claviceps*, *Peziza*, *Morchella*, etc.

○ (Parasexuality in fungi was first described by G. Pontecorvo and Ropers (1952) in *Aspergillus nidulans*).

5. Basidiomycetes (Club fungi):
   - (i) Mycelium is well developed, filamentous, branched and septate, which chiefly passes through 2 stages (a) **Pry. mycelium-haploid** (b) **Sec. or dikaryotic mycelium**, each cell having 2 nuclei ($n + n$).
   - (ii) **Clamp connections** on the dikaryotic hyphae are of universal occurrence.
   - (iii) Except in rusts and smuts, the septum is **dolipore** septum (with a dolipore).
   - (iv) Motile cells are **absent**.
   - (v) Asexual reproduction plays insignificant role in life cycle.
   - (vi) Sex organs lacking. **Sexual reproduction** represented by plasmogamy, karyogamy and immediately followed by meiosis.
   - (vii) **Basidium** is characteristic reproduction organ of Basidiomycetes where both **karyogamy** and **meiosis** occur.
   - (viii) Typically basidium bears 4 basidiospores exogenously (number, however, varies).

e.g., Smuts (*Ustilago*), rusts (*Puccinia*), mushroom (*Agaricus*), *Polyporus*, *Lycoperdon* and *Clavatia*, etc.

○ (*Agaricus* grows in **fairy rings**).

6. **Deuteromycetes** (*Fungi imperfecti*): It is an artificial group, which lacks the sexual stages. These are in fact asexual stages of Ascomycetes or rarely Basidiomycetes, whose sexual stages have not been discovered. Whenever perfect stage is known, it is transferred to its systematic position.

- **Only asexual reproduction** occurs generally by **conidia.** *e.g.*, *Alternaria*, *Colletotrichum*, *Fusarium*, etc.

Some common names of fungi

1. *Saprolegnia* and *Monoblepharis* — **Water moulds**
2. *Rhizopus* — **Bread mould or pin mould** (*Mucor* is also called pin mould)
3. *Penicillium* — **Blue or green moulds**
4. *Saccharomyces* — **Budding yeast or baker's yeast**
5. *Aspergillus* (*Eurotium*) — **Black mould** (weed of laboratory)
6. *Albugo* — **White rust**
7. *Neurospora* — ***Drosophila* of plant Kingdom or red mould (or red bread mould)**
8. *Claviceps* — **Ergot fungi**

○ **'St. Anthony's fire' or 'Holy fire'** disease or condition is caused by eating rye (*Secale cereale*) flour contaminated by ergot alkaloids. In this disease fingers, toes, whole arms, legs, ears or nose become gangrenous and fall off with no bleeding. This was very common during feudal days in Europe.

9. *Peziza* — **Cup fungi**
10. *Morchella* — **Gucchi or True morel or Sponge mushroom**
11. *Ustilago* — **Smut fungi**
12. *Puccinia* — **Rust fungi**
13. *Agaricus* — **Mushroom or Gill fungi**
14. *Polyporus* — **Pore fungi or bracket fungi or shelf fungi**
15. *Lycoperdon and Clavatia* — **Puff ball**
16. *Coprinus* — **Lawyer's wig**
17. *Amanita* — **Poison cup**

○ The Roman king Claudius Caesar was murdered by his wife by giving *Amanita phalloides* and thus *Amanita* is also called **Caesar mushroom.**

18. *Armillaria* — **Honey mushroom**
19. *Geaster* — **Earth-star**
20. *Phallus* — **Stink horn or dead man's finger**
21. *Cyathus* — **Bird's nest fungus**
22. Poisonous mushrooms like *Amanita* are commonly called **'Toad stools'.**
23. *Hydnum* — **Tooth fungi or Hedgehog fungi**
24. *Clavaria* — **Coral fungi**
25. *Tremella* — **Jelly fungus**
26. *Pleurotus* — **Oyster mushroom**

Reproduction in fungi

The fungi reproduce by three methods :
(1) Vegetative (2) Asexual (3) Sexual.

(1) Vegetative reproduction

It takes place by the following methods:

(a) Fragmentation: The hyphae break up into pieces and each piece develops into new plant under favourable conditions, *e.g., Rhizopus, Mucor, Aspergillus, Alternaria*, etc.

(b) Fission: It is the simplest method which involves the splitting of the cell into two daughter-cells by constriction, *e.g., Yeast (Schizosaccharomyces)*.

(c) Budding: Some fungi produce small outgrowths, *i.e.*, buds from their vegetative body and receive one daughter nucleus from parent nucleus through division. After some time, the buds are cut off and mature to form new individuals. Sometimes a chain of buds is formed, which is called **pseudomycelium**. It is common in Yeast and *Ustilago*.

(d) Oidium formation: Sometimes the hyphae break up into numerous fragments known as oidia and give rise to new hyphae, *i.e., Collybia, Coprinus* and *Rhizopus* in sugary solution.

(e) Chlamydospores: Under unfavourable conditions, hyphae form thick-walled resting resistant spores which separate from each other. They may remain viable for several years and on return of favourable conditions, they germinate to give rise to new individuals (organs of **perennation**).

(f) Sclerotia: These are compact masses of hyphae forming pseudo tissues. They serve as organs of perennation and may be formed singly in **ergot** (*Claviceps*) or may be produced in large number from one mycelium in *Botrytis*.

(2) Asexual reproduction

It takes place during favourable conditions. Asexual reproduction in fungi may be of the following types:

(a) Zoospore formation: Zoospores are uninucleate, thin-walled, formed in zoosporangia. They may be **uniflagellate**, *e.g., Synchytrium* or **biflagellate**, *e.g., Saprolegnia, Pythium*. Biflagellate zoospores are of two types:

(i) **Pear-shaped** or pyriform, with 2 flagella placed at anterior end, are known as primary zoospores.
(ii) **Kidney-shaped** or bean-shaped, bearing two oppositely directed flagella inserted laterally in a furrow or concave side (secondary zoospores).

After liberation they swim freely in water, *e.g., Albugo, Pythium, Saprolegnia, Achyla*, etc.

(b) Aplanospore formation: Aplanospores are thin-walled, non-motile spores formed inside sporangium, which give rise to new mycelium, *e.g., Rhizopus, Mucor.*

(c) Conidia: Conidia are non-motile, thin-walled exogenously produced spores on a conidiophore and sometimes they are arranged in chains upon the conidiophore, *e.g., Aspergillus* and *Penicillium* or singly in *Pythium, Phytophthora*.

The tip of the conidiophore is spherical and gives out a number of peg-like branches, sterigmata bearing chains of conidia in *Aspergillus*, while in *Penicillium*, the sterigmata are simply the ends of dichotomous brush-like conidiophore.

(d) Pycniospores: These are small conidia-like bodies produced in flask-shaped cavities called the pycnia, *e.g.*, in *Puccinia*.

(e) Ascospores: These are uninucleate, unicellular non-motile, usually eight in number produced in sac-like structures called ascus, characteristic of **Ascomycetes**.

(f) Basidiospores: Characteristic of **Basidiomycetes**, produced exogenously by club-shaped basidium or sterigma. Usually four basidiospores are produced.

(g) Uredospores and Teleutospores: These are binucleate spores produced in clusters called **uredosori**. Each spore is borne singly at the tip of a stalk, *e.g., Puccinia* produces these two types of spores on wheat leaves.

(3) Sexual reproduction

With the exception of the class **Deuteromycetes**, sexual reproduction occurs in all groups of fungi. It has three distinct phases:

(a) Plasmogamy: This involves union between two protoplasts resulting in bringing the fusing nuclei of different parents close to each other.

(b) Karyogamy: By fusion of two haploid nuclei, a diploid zygote is produced.

(c) Meiosis: Reduction division takes place in zygote, reducing the number of chromosomes to half.

Sexual reproduction is of following types:

(1) Planogametic couplation: In this, fusion of motile gametes of opposite strains takes place. It is known only in a few **Archimycetes**. This process is of three types:

(i) **Isogamy:** Found in most primitive fungi, *e.g., Katenaria* sps. The fusing gametes here are morphologically similar but physiologically dissimilar, *e.g., Synchytrium*.
(ii) **Anisogamy:** The fusing gametes are both morphologically and physiologically different; the male gamete is smaller and more active than female gamete, *e.g., Allomyces*.
(iii) **Oogamy:** The female gamete (egg) is non-motile and the male gamete (antherozoid) is motile.

(2) Gametangial contact: In this two gametangia come in contact; either a passage is formed by dissolution of common wall at the point of contact or a fertilization tube is developed through which the entire contents of male gametangium are migrated into female gametangium, *e.g.*, in *Albugo, Aspergillus, Pythium, Phytophthora*.

(3) Gametangial copulation: In this process fusion of entire contents of 2 gametangia occurs by dissolution of their common walls. Two gametangia ultimately fuse resulting in karyogamy, *e.g., Mucor, Rhizopus*, Yeast.

(4) Spermatization: Many minute spore-like single-celled structures called **spermatia (non-motile male gametes)** are produced by some fungi, which are transferred to special receptive hyphae through water, wind and insects, etc. The contents migrate into receptive structure and dikaryophase is established, *e.g., Puccinia*.

(5) **Somatogamy:** Here two vegetative cells or hyphae take over the sexual function and fuse together, *i.e., Morchella, Peziza* and *Agaricus* are common examples.

Economic importance of fungi

(A) Useful activities

1. **Fungi as food:** Some fungi are used as delicious food. The fructifications of certain fungi are used as nutritious and delicious foods, *e.g., Agaricus bisporus* and *A. campestris* (mushrooms).

Morchella (used in H.P. and Kashmir), *Lycoperdon, Clavatia, Pleurotus, Volvaria, Volvariella*, etc.,are also edible fungi.

Similarly **Yeast** is an important source of vitamin B and D. *Saccharomyces, Endomyces, Rhodotorula, Torulopsis* are rich in proteins.

- ○ A food called **'Sufu'** is produced from *Mucor* and *Antimucor*.

2. **Fungi as medicine:** Fungi are used in the production of different **antibiotics** (substances of microbial origin and having antimicrobial activities).

- ○ The first antibiotic **Penicillin** (wonder drug) was obtained from *Penicillium notatum* by **Sir Alexander Fleming** (1929).

Some important medicines (antibiotics) are:

Source

Penicillin — *Penicillium notatum* and *P. chrysogenum*

Ergotine — *Claviceps purpurea (sclerotia)*: Given after **childbirth**

Griseofulvin — *Penicillium griseofulvum*: In skin diseases (ringworm)

Citrinine — *P. citrinum*

Campestrin — *Psaliotta campestris (Agaricus campestris)*

Baccatin A — *Gibberella baccata*

Glyotoxin — *Trichoderma* sps.

Proliferin — *Aspergillus proliferans*

Chaetomin — *Chaetomium cochloides*

Jawaharine — *Aspergillus niger*

Ephedrine — From benzaldehyde by action of yeast and used in **asthma and nasal troubles.**

Fumigallin — *Aspergillus fumigatus*

Clavicin — *Aspergillus clavatus*

Flavicin — *Aspergillus flavus* and *A. fumigatus*

Besides, many bacteria (Schizomycetes) yield many antibiotics (as already described).

- ○ Also **calvacin, an anticancer substance** is obtained from *Clavatia*, so **eaten to prevent tumour** formation in stomach.

3. **Role of fungi in industries:**

(i) **In alcoholic industry:** Yeast (*Saccharomyces*) has the property of **fermentation** because of **'zymase'** enzyme.

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow[\text{Yeast}]{\text{Zymase}} \underset{\text{Ethyl alcohol}}{2C_2H_5OH} + 2CO_2 \uparrow$$

Ethyl alcohol is the basis of brewing industry.

(ii) **In baking industry:** CO_2 as evolved above raises **'dough'**.

(iii) **Enzymes:** **Taka diastase, digestin and polyzime** are produced from *Aspergillus flavus-oryzae* series.

- **Invertase:** Prepared from *Saccharomyces cerevisiae.*
- **Amylase:** From *Aspergillus oryzae*.
- **Zymase:** From yeast (*Saccharomyces cerevisiae*).

(iv) **Cheese industry:** *Penicillium camemberti* and *P. roquefortii* are used for flavouring cheese.

(v) **Organic acids, *e.g.*, Citric acid:** By *Aspergillus niger* and *A. wentii, Mucor*, etc.

Gluconic acid — By *Aspergillus niger* and *Penicillium purpurogenum*.

Gallic acid — By *P. glaucum* and *A. gallomyces*.

Kojic acid — By *A. oryzae*.

Fumaric acid — By *Rhizopus stolonifer.*

(vi) **Proteins:** Yeast cake is the main source of protein.

4. **Fungi in phytohormones:** Gibberellic acid is obtained from a fungus *Fusarium moniliforme* (*Gibberella fujikuroi*).

5. **In genetic and other biological studies:**

- *Neurospora sitophila* (Red mould) has short life cycle and hence used in **genetical and biochemical studies.** Also Yeast and *Ascobolus*.

6. **As trace organisms:** Some strains of *Aspergillus niger* are highly sensitive to some trace elements. They can detect trace-elements like Cu, Zn, Mo, Mn, Cd, Pb, etc., even if they are present in very small quantity in the substrate. These elements when taken up by fungus may give particular colour to fungus.

7. **Fungi in agriculture:**

(i) **Soil fertility:** Saprophytic fungi live upon dead organic matter and thus break down complex substances into simple ones, which are again absorbed by plants.

(ii) **In biological control:** Soil inhabiting fungus *Trichoderma* kills *Pythium* fungus (root rot fungus). Similarly *Penicillium vermiculatum* checks *Rhizoctonia solani*.

- **Predacious fungi** like *Dactyllela, Dactylaria, Zoophagus* and *Arthrobotrys*, etc., destroy certain nematodes, eelworms, etc., causing plant diseases.

(iii) **Importance as mycorrhiza:** Association of fungi and roots of higher plants is called mycorrhiza.

e.g., Rhizoctonia, Phoma, Boletus, Tricholoma, Phallus, etc., live in association of roots of higher plants. They help in absorption of water and nutrients and in turn get ready-made food (symbiosis).

(iv) **In soil aggregation:** *Absidia, Aspergillus, Clado-*

sporium, Mucor, Penicillium and *Rhizopus* have soil binding property (by mucilage) and they make the soil good.

(v) As insecticides: Many insect pests can be controlled by use of fungi like *Aschersonia aleyroides, Isoria ferinosa, Empusa*, etc.

(B) Harmful activities

1. Plant diseases:

(i) Black wart disease of potato—*Synchytrium endobioticum*
(ii) White rust of crucifers—*Albugo candida* or *Cystopus candidus*
(iii) Late bligut of potato—*Phytophthora infestans*

- (Famous famine of Ireland (1845) is associated with this disease which caused death of lakhs of people).

(iv) Early blight of potato—*Alternaria solani*
(v) Powdery mildews—*Erysiphe* sps.
(vi) Damping of seedlings—*Pythium* sps.
(vii) Loose smut of wheat—*Ustilago tritici*
(viii) Black rust of wheat—*Puccinia graminis-tritici*
(ix) Apple scab—*Venturia inaequalis*
(x) Downy mildews—*Peronospora* sps.
(xi) Red rot of sugar cane—*Colletotrichum falcatum*
(xii) Tikka disease of groundnut—*Cercospora* sps.
(xiii) Stem gall of coriander—*Protomyces* sps.
(xiv) Wilt of arhar—*Fusarium* sps.
(xv) Leaf rust of coffee—*Haemelia vastatrix*
(xvi) Blast disease of rice—*Pyricularia oryzae*
(xvii) Green ear disease of bajra—*Sclerospora graminicola*
(xviii) Flag smut of wheat—*Urocystis tritici*
(xix) Maize smut—*Ustilago maydis*
(xx) Loose smut of oat—*Ustilago avenae*
(xxi) Covered smut of oat—*U. kolleri*
(xxii) Covered smut of jowar (*Sorghum*)—*Sphacelotheca-sorghii*
(xxiii) Leaf spot of rice—*Helminthosporium oryzae*

- Severe famine of Bengal (1943) which caused death of a large number of people was due to this disease.
- **Phytoalexins** (*Phyton* = plant + *alexin* = warding off substances or compounds) are antibody-like materials or chemical substances produced in host plant body after infection by microbes like fungi, bacteria and viruses or as a response to mechanical and chemical injury. These substances are mostly **phenolic compounds.** The term 'phytoalexins' was given by **Muller and Borger (1940).** These phytoalexins **inhibit** the development of pathogens in general and **fungal pathogens in particular,** *e.g.*, **Rishitin** (produced in potato infected by *Phytophthora infestans*), **Pisatin, Phaseolin,** etc.

2. Human diseases: Some important ones are :

(i) Aspergillosis (lung disease) – *Aspergillus niger, A. flavus, A. fumigatus*
(ii) Ring worm—*Trichophyton, Microsporum*
(iii) Neuritis (Infection of nervous system)—*Mucor pusillus*
(iv) Mental disorder (Cryptococcosis)—*Lipomyces neoformans*
(v) Ear infection (Automycosis)—*Aspergillus flavus, A. nidulans*
(vi) Thrush disease of throat—*Monilia*

3. Animal diseases:

(i) Athlete foot—*Tinea rubrum*
(ii) Ringworm—*Trichophyton, Microsporum, Epidermophyton*
(iii) Mucomycosis—*Mucor, Rhizopus*
(iv) Aspergillosis—*Aspergillus*
(v) Penicillosis—*Penicillium*

4. **Spoilage of foodstuffs:** Spores of *Rhizopus, Mucor, Aspergillus* germinate on jam, jellies, pickles, bread, etc., and destroy them. *Penicillium, Mucor* and *Aspergillus* destroy meat.

5. **Destruction of timber:** *Polyporus* (Pore fungi) causes wood rot. Also *Armillaria mellea* causes red rot of apple and other trees.

6. **Destruction of common goods:** *Alternaria, Penicillium, Trichoderma, Mucor, Chaetonium, Cephalothecium* and *Fusarium* destroy leather, cloth, rubber, paper, camera lenses, etc.

7. **Fungi as poison:** *Amanita phalloids* (like *Agaricus*) is highly poisonous and fatal to man. *Boletus* is also poisonous.

- Aflatoxins are **mycotoxins** produced by *Aspergillus flavus, A. fumigatus, Penicillium islandicum*, etc. There are 8 forms (Like B_1, B_2, G_1, G_2, etc.) of aflatoxins, which are derivatives of **furanocoumarin.** These bind with DNA and **prevent transcription,** hence protein synthesis. These cause liver cancer in animals and men.

8. **Hallucinogenic fungi:** These cause **distortion of perception.**

e.g., LSD or lysergic acid is extracted from *Claviceps* fungus (hallucinogenic).

RHIZOPUS

Systematic position

Kingdom	—	Mycota
Division	—	Eumycota
Sub-division	—	Zygomycotina
Class	—	Zygomycetes
Order	—	Mucorales
Family	—	Mucoraceae
Genus	—	*Rhizopus*

Habitat

Rhizopus **is a saprophytic fungus represented by 50 species.** It grows on dead organic matter. The common species of *Rhizopus* are ***R. stolonifer*** (known as bread mould), ***R. oryzae, R. sexualis.*** Some species are weak parasites; for instance, ***R. artocarpi*** (causes fruit drop of jackfruit) and ***R. arrhizus*** (causes fruit rot of apples). ***R. stolonifer*** causes soft rot of sweet potato and leak disease of strawberries.

Several species are capable of synthesizing important industrial products, *R. nodosus* in lactic acid fermentation, *R. oryzae* in alcoholic fermentation and *R. stolonifer* in manufacture of fumaric acid.

Vegetative structure

Rhizopus occurs as white cotton like mycelium which is coenocytic and profusely branched. Three types of hyphae are recognised in the mycelium:

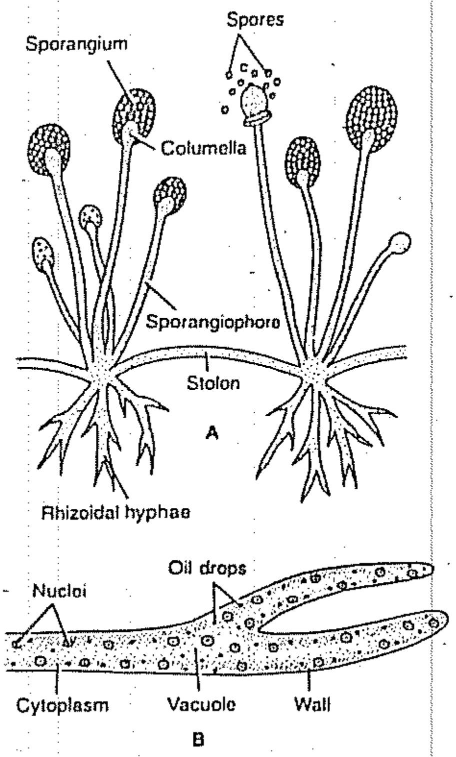

Spores
Sporangium
Columella
Sporangiophore
Stolon
A
Rhizoidal hyphae
Oil drops
Nuclei
Cytoplasm
Vacuole
Wall
B

Fig. 11.2. *Rhizopus*: **A.** Mycelium with three types of hyphae (Rhizoidal, Stoloniferous and sporangiophore) **B.** Portion of hyphae showing microscopic structure

(i) **Stolons or stoloniferous hyphae:** These grow horizontally above the substratum and are stout and less branched.

(ii) **Rhizoidal hyphae:** These are repeatedly branched which penetrate the substratum and absorb water and nourishment from it.

(iii) **Sporangiophores:** These are erect, aerial and unbranched hyphae which grow upwards in tufts (3–5) from the stolons. The sporangiophores bear terminal sporangia and are thus reproductive in function.

The hyphae are coenocytic, aseptate and branched. It has many nuclei, oil drops, glycogen bodies and vacuoles in the cytoplasm. The hyphal wall is microfibrillar and consists of chitin-chitoson.

Reproduction

It reproduces by vegetative, asexual and sexual methods.

(A) Vegetative reproduction: It takes place by **fragmentation.** The vegetative hyphae (stolons) break up into small fragments. Each fragment is capable of developing into new mycelium.

(B) Asexual reproduction: The asexual reproduction takes place by the formation of **aplanospores** or by **chlamydospores.**

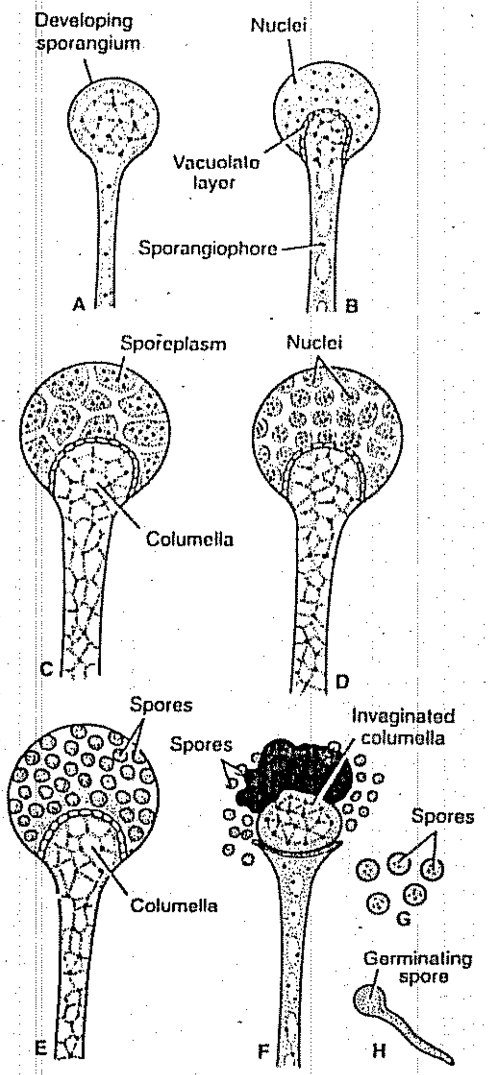

Developing sporangium
Nuclei
Vacuolate layer
Sporangiophore
A
B
Sporeplasm
Nuclei
Columella
C
D
Spores
Invaginated columella
Spores
Spores
Columella
G
Germinating spore
E
F
H

Fig. 11.3. Stages in asexual reproduction (aplanospore formation) in *Rhizopus*

(i) **Aplanospores formation:** It takes place during favourable conditions. The multinucleate non-motile spores known as aplanospores are formed inside the round black sporangia occurring singly at the tip of sporangiophores.

At the time of sporangium formation, the tip of the sporangiophore swells and the nuclei divide repeatedly. The contents of the tip differentiate into a **central zone**, filled with vacuolated cytoplasm surrounded by a **peripheral zone** containing dense cytoplasm with many nuclei. The two zones are separated by a protoplasmic layer containing narrow flattened vacuoles which fuse laterally and ultimately develops into a dome-shaped septum, known as **columella.** In the mean time cytoplasm divides into innumerable, small 2–10 nucleate portions which round up, get invested with spore membranes and develop into **nonflagellate** spores, the sporangiospores, which are globose to ellipsoidal with a thin smooth wall. Spores are dispersed by bursting of the thin wall of the sporangium due to pressure set up in the columella exerted by the absorption of water in sporangium and columella. The spore on germination produces a germ tube and thus forms a new mycelium.

(ii) **Chlamydospore formation:** During unfavourable conditions, the mature mycelium becomes septate and the protoplast of each cell forms a rounded and thick-walled structure, the chlamydospore. These perennating bodies on getting suitable conditions germinate and form new mycelia.

(iii) **By oidia:** The mycelium growing in sugary medium breaks up into numerous small fragments called oidia. They separate from each other and increase by yeast like budding. This stage is called **torula** stage. Each of these segments grows into new mycelium.

(C) **Sexual reproduction:** Sexual reproduction takes place by the formation of two multinucleate aplanogametangia which are morphologically similar but physiologically dissimilar. Most of the species of *Rhizopus* are **heterothallic,** but a few (*e.g., R. sexualis*) are **homothallic.**

When two mycelia of opposite strain (+) and (–) come near, the mycelia develop small outgrowths **progametangia.** The apical ends of these progametangia which are swollen and filled with protoplasm come in contact and a septum is laid down separating the terminal portion **aplanogametangium** from the basal part, called **suspensor.**

As the two gametangia mature, the separating wall dissolves and mixing of the contents takes place by nuclear pairing and fusion of one (+) and another (–) giving rise to a number of diploid nuclei (gametangial-copulation). The young zygospore secretes several layers of thick wall around it. On maturation the zygospore breaks up the original gametangial wall into small pieces and the outer thick spiny and black exosporium is exposed. The wall of the mature zygospore is a 5-layered structure (2 in exosporium and 3 in endosporium).

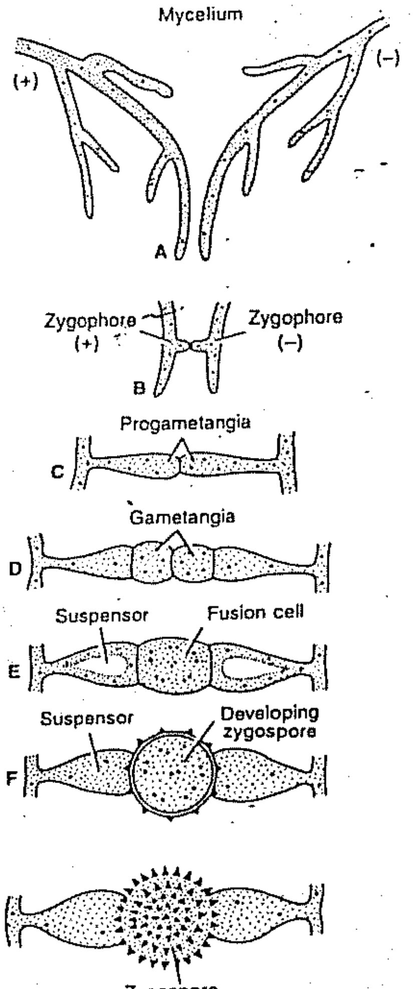


Fig. 11.4. Stages in sexual reproduction in heterothallic species of *Rhizopus*

Germination of zygospore: The zygote germinates after resting period. Exosporium cracks and endosporium produces a germsporangiophore or promycelium that terminally develops a germsporangium with large number of spores. Meiosis occurs at the time of germination of zygospore. The spores germinate with the help of germ tubes to form new mycelium.

- **Heterothallism:** **A.F. Blakeslee** (1904), an American scientist, observed a **characteristic** phenomenon in order **mucorales** (*Rhizopus*), called **heterothallism.**

Most of the sps. of *Rhizopus* are **heterothallic,** *i.e.,* **sexual reproduction** or **zygospore formation** occurs only **between 2 oppositely strained** (+ and –) **hyphae.** This was supported experimentally by him.

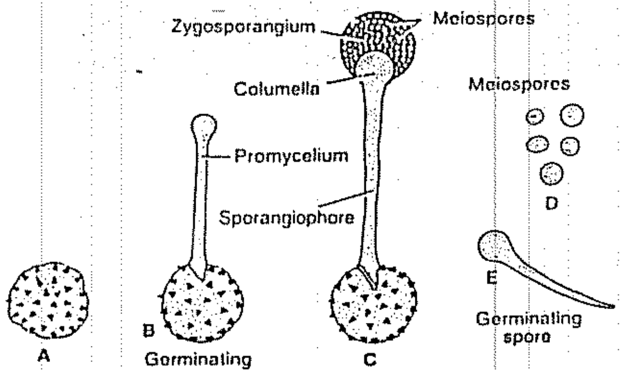

Zygosporangium
Meiospores
Columella
Meiospores
Promycelium
Sporangiophore
D
E
Germinating spore
A
B
Germinating zygospore
C

Fig. 1.1.5. A–D. Germination of zygospore and formation of spores E. Germination of spore, in *Rhizopus*

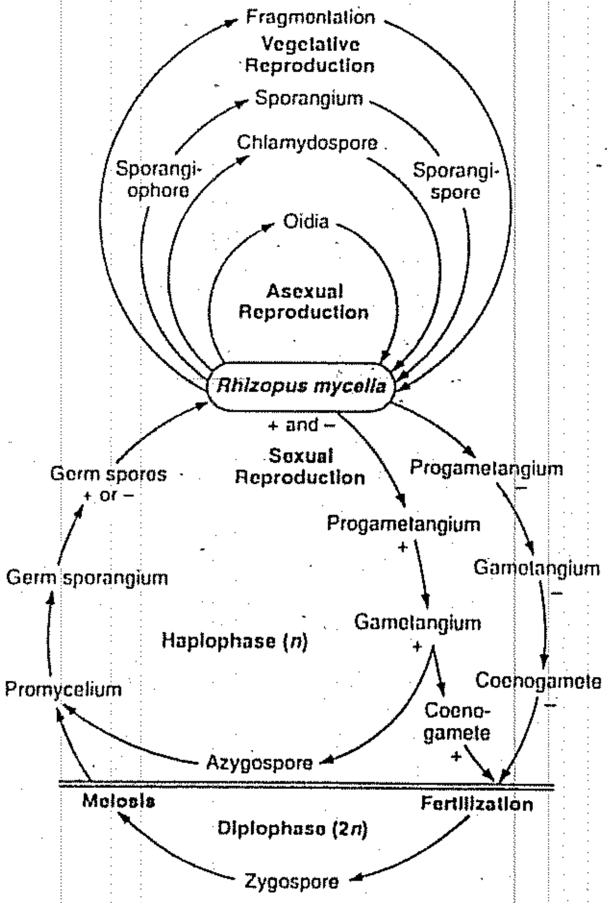

Fragmentation
Vegetative Reproduction
Sporangium
Chlamydospore
Sporangiophore
Sporangispore
Oidia
Asexual Reproduction
Rhizopus mycelia
+ and –
Sexual Reproduction
Progametangium
Germ spores + or –
Progametangium +
Germ sporangium
Gametangium –
Gametangium +
Haplophase (n)
Promycelium
Coenogamete –
Coenogamete +
Azygospore
Meiosis
Fertilization
Diplophase (2n)
Zygospore

Fig. 11.6. Graphic representation of life cycle of *Rhizopus*

Points of distinction between *Mucor* and *Rhizopus*

Mucor is another member of family **Mucoraceae.** It resembles with *Rhizopus* except for a few minor differences. The points of distinction between *Rhizopus* and *Mucor* are as follows:

Rhizopus	*Mucor*
1. Commonly grows on bread.	1. Commonly grows on horse dung (coprophillous).
2. Mycelium is differentiated into 3 types of hyphae stoloniferous hyphae, rhizoidal hyphae and sporangiophores.	2. Mycelium is undifferentiated, *i.e.*, having only one type of hyphae.
3. As rhizoids are present hence food material is absorbed mainly by rhizoids or rhizoidal hyphae.	3. Rhizoids absent and food is absorbed by entire surface of mycelium.
4. Sporangiophores or upright hyphae arise in tufts (3–5) from stolons opposite the rhizoids.	4. Sporangiophores arise singly from any point of mycelium.
5. Reduction division or meiosis occurs during germination of zygospore after resting period	5. R.D. occurs soon after karyogamy (before resting period of zygospore).

YEAST

Systematic position

Kingdom — Mycota
Division — Eumycota
Sub-division — Ascomycotina
Class — Hemiascomycetes
Order — Endomycetales
Family — Saccharomycetaceae
Genus — *Saccharomyces*

Yeasts were first of all reported by Leeuwenhoek (1680). Yeast is the smallest fungus.

- Yeasts are of 3 types :
  1. **Budding yeast:** Here budding is the chief method of reproduction, *e.g.*, *Saccharomyces cerevisiae* **(Baker's yeast or Brewer's yeast).**
  2. **Fission yeast:** Here cell divides by transverse wall or septum or **fission** is the chief method of reproduction, *e.g.*, *Schizosaccharomyces octosporus.*
  3. **Helobial yeast:** Here both budding and fission occur, *i.e.*, intermediate between the first two, *e.g.*, *Saccharomycodes ludwigii.*
- Common yeast is *Saccharomyces*, which is commonly known as **brewer's yeast or baker's yeast.**
- *Saccharomyces* or yeast is ascomycetes saprophytic fungus, which grows on **sugary solution.**
  Besides sugar, yeast requires N and S and hence it grows on the surface of certain fruits, *i.e.*, grapes and *Phoenix.*
- Yeast also grows on such soils where there are present grape vines.
- In the laboratory, yeast can be grown by placing few grains of yeast cake on sugar solution or solution of molasses and water.

Somatic structure

There is no well developed mycelium but yeast is a **unicell** which may be oval or spherical in shape.

Yeast unicell is generally 2–8 μ in diameter and 3–15 μ in length. The cell is surrounded by a rigid cell wall which is having proteins (7–8%), lipids (8.5–13.5%), chitin (1–2%). Besides, there are 2 important polysaccharides glucan (30–35%) and mannan (about 30%).

- Cellulose is altogether absent in cell wall of yeast.
- Inside the cell wall is present **protoplasm,** which is divided into outer portion called **ectoplasm** and inner granular portion called **endoplasm.** In the endoplasm are present two important organelles, *i.e.*, **mitochondria** and **ribosomes** (80-S type). Besides, reserve food materials are present in the form of granules, *i.e.*, **glycogen granules, few protein granules and oil globules.**
- In the centre of cell is present a large **central vacuole** and on one side of this vacuole is present **nucleus,** which is generally less than 1 μ in diameter. From the nucleus arise some **dark staining threads,** which are present around central vacuole. Central vacuole is also known as **volutin vacuole,** *i.e.*, vacuole having solution of volutin (RNA + lipoproteins + polymetaphosphates).

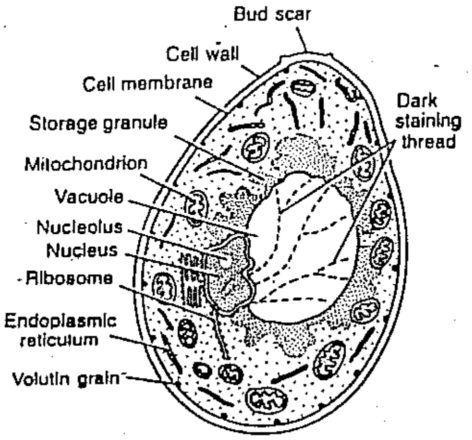


Fig. 11.7. Electron microscopic cell structure of *Saccharomyces* (yeast)

Nutrition

Because it lacks chlorophyll, so it is **saprophytic** in its mode of nutrition. On the substrate, it secretes enzymes and these enzymes are collectively known as **zymase.** (It is a multienzyme complex.)

Zymase breaks down starch or complex carbohydrate into simple sugars which are taken up by yeast.

- In complete absence of oxygen, *i.e.*, in anaerobic condition, **fermentation** occurs. This fermentation property of yeast is the **basis of baking as well as brewing industry.**

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow[\text{Yeast}]{\text{Zymase}} \underset{\text{Ethyl alcohol}}{2C_2H_5OH} + 2CO_2 \uparrow$$

- (C_2H_5OH is the basis of brewing industry, whereas CO_2 is the basis of baking industry in which CO_2 is used for raising dough).

Growth

Growth in yeast unicell is over the whole surface.

Reproduction

Occurs by:

1. Vegetative or asexual method.
2. Sexual method.

1. Vegetative or asexual reproduction: The most common method of reproduction in *Saccharomyces* is **budding** and hence it is also known as **budding yeast.**

Under favourable conditions, *i.e.*, in conditions of plenty of nutrients, budding occurs. During budding cell wall becomes thin or soft at one end and from this point, an outgrowth arises which is known as bud. Meanwhile the nucleus divides mitotically into two and out of these two nuclei, one flows into the bud. [Some workers consider it as **amitotic division**]. This bud enlarges and is constricted off from the parent cell. This bud further enlarges and achieves normal size of yeast unicell. This is **unipolar budding.**

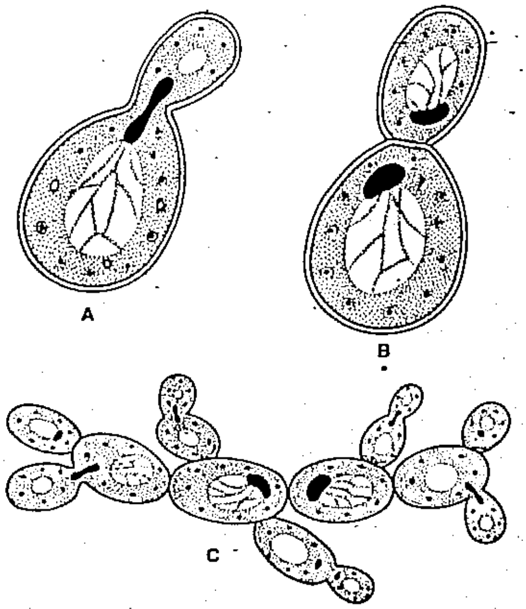


Fig. 11.8. A–B. Vegetative reproduction by budding in *Saccharomyces cerevisiae* C. Pseudomycelium formation

- The place from where the bud is detached achieves concavity, which is known as **birth scar.**
- Under more favourable conditions, the bud formation may occur simultaneously at both ends, which is known as **bipolar budding.**
- Under highly favourable conditions, bud formation occurs

so quickly that a long row (upto 64 cells) of cells is formed, which is known as **pseudomycelium**.

2. **Sexual reproduction:** In yeast, definite sex organs, *i.e.*, antheridium and ascogonium, are **absent**, but the characteristic spores of ascomycetes, *i.e.*, **ascospores**, are produced.

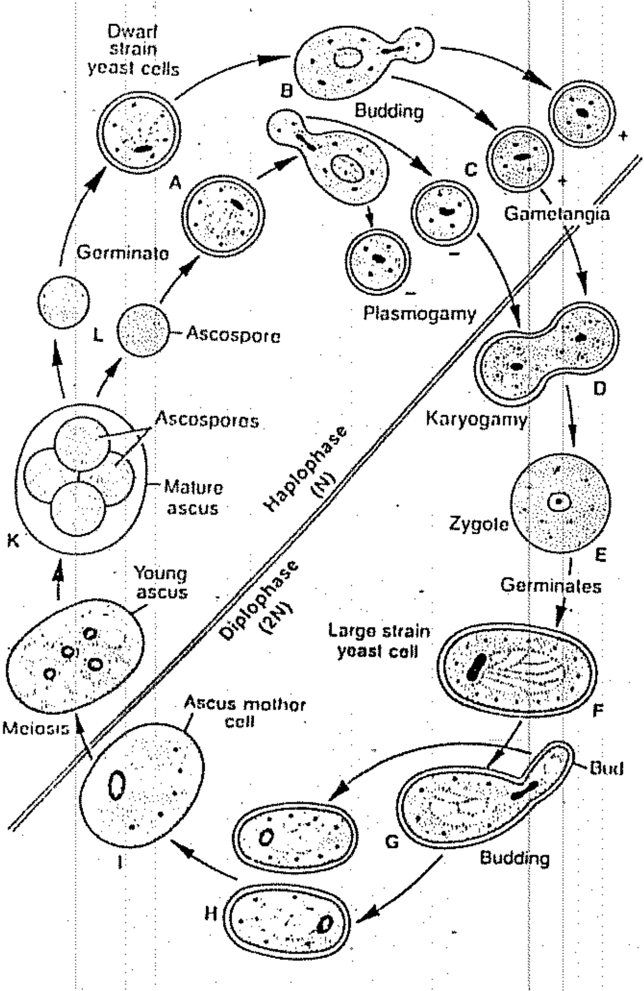


Fig. 11.9. Sexual cycle in *Saccharomyces cerevisiae*

- 3 characteristics of sexual reproduction present in yeast are :
  - (i) Plasmogamy (sexual fusion)
  - (ii) Karyogamy (fusion of nuclei)
  - (iii) Meiosis or reduction division.
- In *Saccharomyces cerevisiae* (baker's yeast or brewer's yeast), there are 2 types of cells:
  - (a) Dwarf yeast cells
  - (b) Large yeast cells.

(a) **Dwarf yeast cells:** Smaller in size, **haploid**, formed by germination of haploid ascospores and are **rounded** in shape.

(b) **Large yeast cells:** Larger in size, **diploid** (being zygotes), **oval** in shape.

The dwarf yeast cells multiply vegetatively by budding and under certain conditions, two normal dwarf yeast cells (one of + strain, other of − strain) act as *gametangia*, *i.e.*, + gametangium and − gametangium.

Fusion of these two gametangia occurs, *i.e.*, sexual reproduction, by **gametangial copulation.** Entire contents of two gametangia fuse. First **plasmogamy** occurs which is followed by **karyogamy** and thus zygote is formed (2*n*). The zygote enlarges in size, achieves oval shape and constitutes large strain yeast cell. These large strain yeast cells also multiply by budding and these directly act as **ascus mother cell** or **ascus.** Reduction division occurs in ascus and **four ascospores** are produced (2 of + strain and 2 of − strain). The ascospores are liberated by rupture of wall of ascus and these haploid + and − ascospores give rise to dwarf yeast cells of + and − strain.

Thus in life cycle of *Saccharomyces cerevisiae*, both haploid and diploid phases are equally represented and thus life cycle pattern is **haplo-diplobiontic** or **haplodiplontic.**

- In **fission yeast** (*Schizosaccharomyces octosporus*), life cycle pattern is **haplobiontic,** *i.e.*, diploid phase is greatly reduced and is represented by zygote whereas haploid phase is more prominent. Further number of ascospores produced per ascus is **8.**
- In **helobial yeast** (*Saccharomycodes ludwigii*), life cycle pattern is **diplobiontic** as haploid phase is greatly reduced represented only by ascospores whereas diploid phase is more prominent. Further number of ascospores produced per ascus are **4.**
- **(Number of ascospores produced per ascus in yeasts is 4 or 8).**

Besides these some other characteristic phenomena occur in yeast as:

- **Adelphogamy:** Fusion between two sister cells.
- **Pedogamy:** Fusion between mother cell and daughter cell.
- **Parthenogamy:** Formation of ascus or zygote without fusion.

Economic importance of yeast

Useful activities:

1. By virtue of their fermentation property, yeasts are used in **baking** as well as **brewing** industry (specially *Saccharomyces cerevisiae*).
2. **Invertase** enzyme is produced by *Saccharomyces cerevisiae.*
3. Yeast cells are pressed with starch to form **yeast cake** which is rich source of protein and vitamins, *i.e.*, **vit. B_1** (thiamine), **vit. B_2** (riboflavin), **vit. C (ascorbic acid).**
4. Filamentous yeast, *i.e.*, *Ashby gossypi* is a rich source of **vit. B_2** (riboflavin).

Harmful activities: Some human diseases are caused by yeast, *e.g.*, **cryptococcosis-meningitis,** is caused by a yeast called *Cryptococcus neoformans*. Similarly **thrush disease** is caused by *Candida albicans* yeast.

- Some food materials including fruits are also destroyed by some species of yeast.

CHARACTERISTIC FEATURES OF SOME OTHER IMPORTANT FUNGI

1. ALBUGO OR CYSTOPUS

Systematic position

Kingdom — Mycota
Division — Eumycota
Sub-division — Mastigomycotina
Class — Oomycetes
Order — Peronosporales
Family — Albuginaceae
Genus — *Albugo* (*Cystopus*)

- It is an **obligate parasite** which causes **white rust** disease in members of different families like Cruciferae (Brassicaceae), Compositae (Asteraceae), Convolvulaceae, etc.
- Most common species is *Albugo candida* or *Cystopus candidus*, which causes 'white rust of crucifers' in which rusty white pustules are formed on lower surface of leaves (which may spread to upper surface also) and stem. These infected parts (leaves, stem and flowers) become abnormal due to **hypertrophy, fleshiness** and **distortion.** Reproductive parts of flower (stamens and carpels) become **sterile** and growth of plant is **stunted.**

Vegetative structure

The mycelium of the fungus is **intercellular, branched, aseptate, multinucleate (coenocytic)** with **knob-like haustoria** (having stalk and head) which absorb food from host cells.

Reproduction

Albugo reproduces both by asexual and sexual methods.

- Asexual reproduction occurs by multinucleate **conidia** or **sporangia,** which develop on short, erect, club-shaped **conidiophores** or **sporangiophores** in long **basipetal chains** (youngest at base and oldest at apex). A mucilaginous disc or **disjunctor** is present between two successive conidia. Due to pressure exerted by conidial chains, epidermis ruptures and conidia are seen on host surface in the form of white, rusty pustules (hence called 'white rust'). Conidia are dispersed by wind or rain splashes. In favourable conditions, they germinate by forming usually 8 **reniform** or kidney-shaped **laterally biflagellated zoospores** (flagella unequal, posterior of whiplash type and anterior of tinsel type), which get encysted after some time and then germinate forming germ-tubes which enter through host epidermis and form new mycelia. In unfavourable conditions, conidia germinate directly.
- The male and female sex organs are **antheridium** and **oogonium** respectively, which develop side by side. Sexual reproduction occurs by **gametangial contact.** The oogonium is differentiated into **uninucleate ooplasm** and peripheral **periplasm.** The antheridium is club-shaped and forms a slender fertilization tube that penetrates the periplasm and reaches ooplasm (egg). The fertilized egg secretes a thick wall and is called oospore (2–3-layered wall). The presence of oospores is externally indicated by hypertrophy.
- Meiosis or R.D. occurs in diploid oospore, which is followed by mitotic divisions to form numerous reniform, biflagellated zoospores, which germinate on suitable host by means of germ tubes and form new mycelia.

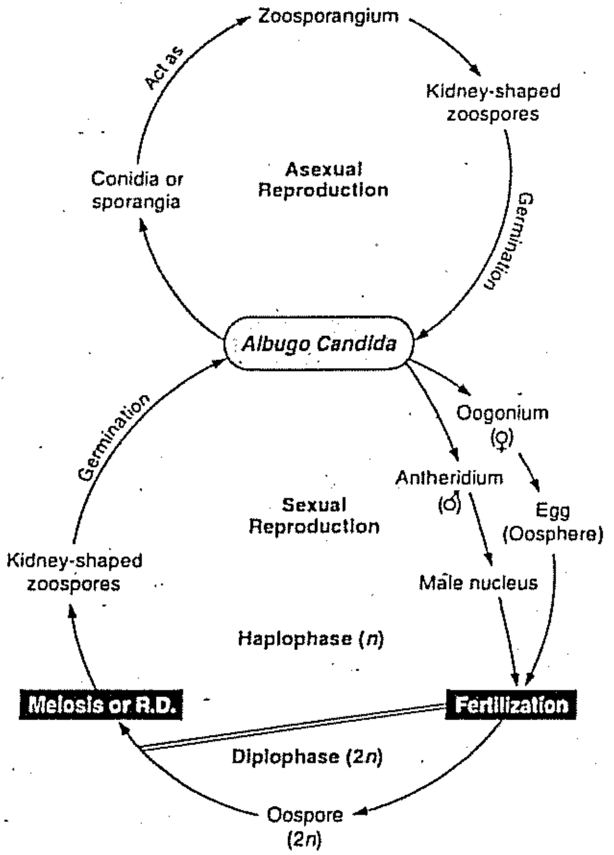


Fig. 11.10. Schematic representation of the life cycle of *Albugo candida*

2. PUCCINIA (Rust Fungi)

Systematic position:

Kingdom — Mycota
Division — Eumycota
Sub-division — Basidiomycotina
Class — Teliomycetes
Order — Uredinales
Family — Pucciniaceae
Genus — *Puccinia*

- It is a large genus having about 1800 species. The species of *Puccinia* are internal **obligate parasites.**
- Some species of *Puccinia* are **autoecious** (completing their life cycle on single host) and others are **heteroecious** (completing their life cycle on two different hosts).
- Three species of *Puccinia* cause considerable loss to wheat crop in India, *i.e.*,
  (i) ***Puccinia graminis*** causes **black rust or stem rust.**
  (ii) ***Puccinia striiformis*** (*P. glumarum*) causes **yellow rust or stripe rust.**
  (iii) ***Puccinia recondita*** causes **brown rust or leaf rust.**
- *Puccinia graminis* (causing black rust or stem rust of wheat and other cereal crops) is an **obligate parasite** and this is confined to stem and leaf sheaths. This is the most common rust of cereals. It is **heteroecious** fungus. **Dikaryophase** occurs in **primary host** (wheat) and **haplophase** occurs in **alternate host** (*Berberis vulgaris*).
- *Puccinia graminis* has 6 strains, *e.g.*, *P. graminis tritici*, *P. graminis secalis*, *P. graminis avenae*, etc., (which infect wheat, rye, oat respectively). Further, each strain has a large number of physilogical races, *e.g.*, about 300 races are present in *P. graminis tritici*. So *Puccinia graminis* shows **physiological specialization** or **biological specialization** (a specific host is affected by specific pathogen).

Vegetative structure

In *P. graminis tritici*, two types of mycelia, *i.e.*, dikaryotic and monokaryotic, are present in life cycle. Both of these mycelia are **intercellular, septate and branched** and septum is having a **simple pore.** Each cell of **dikaryotic mycelium** is having a dikaryon and it occurs in wheat plants or primary host whereas each cell of **monokaryotic mycelium** is having a single nucleus and it occurs in barberry bushes or alternate host. Both types of mycelia are having **spherical haustoria.**

Life cycle

P. graminis tritici is **macrocyclic rust,** *i.e.*, **5 types of spores** are produced in its life cycle, which develop in two hosts in definite sequence as:

(i) Uredospores (ii) Teleutospores	on primary host or wheat
(iii) Basidiospores	on straw or ground
(iv) Pycnidiospores (v) Aeciospores	on alternate host or barberry

- Uredospores and teleutospores are produced on dikaryotic mycelium in primary host or wheat plants. Each **uredospore is stalked, oval, unicellular** and **binucleate.** The uredospores reinfect wheat plants and thus spread the disease. They cannot infect alternate host. During the late wheat season, teleutospores are produced in place of uredospores. Each **teleutospore** is **stalked, bi-celled,**

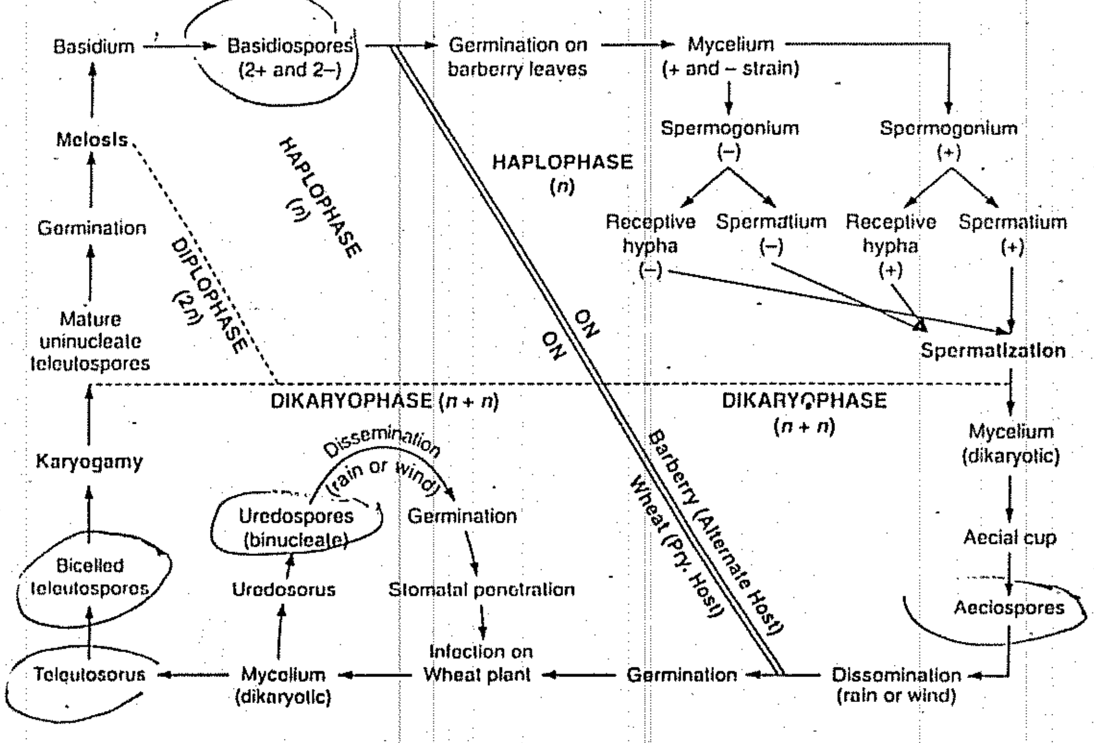

Basidium
Basidiospores (2+ and 2–)
Germination on barberry leaves
Mycelium (+ and – strain)
Spermogonium (–)
Spermogonium (+)
HAPLOPHASE (n)
HAPLOPHASE (n)
Meiosis
Germination
DIPLOPHASE (2n)
Receptive hypha (–)
Spermatium (–)
Receptive hypha (+)
Spermatium (+)
Spermatization
Mature uninucleate teleutospores
ON
ON
DIKARYOPHASE (n + n)
DIKARYOPHASE (n + n)
Karyogamy
Dissemination (rain or wind)
Barberry (Alternate Host)
Wheat (Pry. Host)
Mycelium (dikaryotic)
Uredospores (binucleate)
Germination
Aecial cup
Bicelled teleutospores
Uredosorus
Stomatal penetration
Aeciospores
Teleutosorus
Mycelium (dikaryotic)
Infection on Wheat plant
Germination
Dissemination (rain or wind)

Fig. 11.11. Schematic representation of the life cycle of *Puccinia graminis*

spindle-shaped and each cell is binucleate. The teleutospores act as resting spores and cannot reinfect wheat plants. They germinate in soil in the next spring.

- The teleutospores germinate in spring. Each cell of teleutospore produces one germ tube (promycelium or epibasidium). The diploid nucleus (formed by fusion) of each cell undergoes R.D. and thus each promycelium produces 4 basidiospores (n) on sterigmata (2 of + strain and 2 of – strain). Basidiospores are small, unicellular, **thin-walled** and **haploid**. These basidiospores are disseminated by wind and can germinate only on leaves of alternate host or barberry. They perish in absence of alternate host.
- The basidiospores (n) germinate on leaves of alternate host (barberry) and thus form monokaryotic mycelium (+ and – strain). This mycelium forms flask-shaped **spermogonia** or **pycnidia** on upper surface of leaves. The wall of pycnidium is lined internally by **spermatiophores** or **pycniophores**, each of which produces many small **uninucleate spermatia** or **pycniospores** or **pycnidiospores**. These may be of + or – strain. These spermatia or pycniospores can neither infect primary host nor alternate host. Inside the pycnidium, there are also present **flexous hyphae** (receptive hyphae) and **periphyses**, which came out through ostiole or pore of pycnidium. Now the spermatia or pycniospores of one strain are transferred to flexous hyphae of opposite strain by insects (**spermatization**) and as a result of which, **dikaryotic mycelium** is formed, which forms **inverted cup-like** structures called **aecidia** on lower surface of barberry leaves. In an aecidium, aecidiophores are present which cut off many **binucleate cells** in a chain called **aecidiospores** or **aeciospores**. These aeciospores are not capable of infecting barberry plants but can infect wheat plants (primary host) to form **dikaryotic mycelium** in primary host or wheat and thus complete the life cycle of this heteroecious fungus.

○ Dr. K.C. Mehta (1922–50) studied the problem of annual recurrence of wheat rust in India and concluded that uredospores survive on collateral hosts (grasses) at a height above 1450 m, which infect the regular wheat crop in hills in November. **Uredospores** are formed on stem and leaves of wheat plants during favourable conditions, which act as primary source of infection in plains and are **responsible for recurrence of wheat rust year after year** (aeciospores formed on barberry in July cannot survive till October and hence cannot act as source of infection in wheat).

○ According to **Dr. L.M. Joshi** (1974–86), uredospores surviving at different heights in Himalayas do not form a source of infection of crops in Indo-Gangetic plains but **stem rust inoculum lies in the southern hills.**

3. AGARICUS (PSALLIOTA) (Mushroom)

Systematic position:

Kingdom	—	Mycota
Division	—	Eumycota
Sub-division	—	Basidiomycotina
Class	—	Hymenomycetes
Order	—	Agaricales
Family	—	Agaricaceae
Genus	—	*Agaricus*

- *Agaricus* or *Psalliota* is a saprophytic fungus (present on manure heaps, decaying leaves, wood logs, etc., in rainy season).
- Out of 17 species present in India, 2 species are common edible mushrooms, *i.e.*, *Agaricus campestris* and *Agaricus bisporus*.

Structure of vegetative mycelium

Underground vegetative mycelium is of two types— **Primary mycelium** or monokaryotic mycelium, produced by germination of basidiospore and it is hyaline, septate, short-lived and of **two strains** (+ and –). **Secondary mycelium** or dikaryotic mycelium (commonly called spawn) is formed by **fusion of** primary mycelia of two opposite strains and it is perennial, branched, septate (**dolipore septa**).

- The dikaryotic mycelium is interwined to form dense cord like structures called **rhizomorphs**, which show centrifugal growth. At their maturity, **fruiting bodies** or basidiocarps are formed at tips in more or less circular rings called **'Fairy rings'**. (According to ancient belief, they marked the circular paths of dancing fairies)

Structure of fruiting body

Basidiocarp or fruiting body is commonly called **mushroom**, is differentiated into a **stalk** or **stipe** and a **cap** or **pileus** (umbrella shaped). On undersurface of pileus, gill cavity with **300–600 gills** or **lamellae** is present.

Reproduction

Agaricus reproduces by vegetative, asexual and sexual methods.

- Vegetative propagation is by small pieces of dikaryotic mycelium. Asexual reproduction (rare) takes place by **chlamydospores.**
- Sexual reproduction occurs **without sex-organs.** There is **somatogamous fusion** involving plasmogamy, karyogamy and meiosis (features of sexual reproduction). Somatogamy results in formation of dikaryotic mycelium, which develop fruiting bodies or basidiocarps.
- Each gill or lamella inside gill cavity is having central mass of compactly arranged dikaryotic mycelium called **trama**, on either side of it is a layer of small, rounded cells called **sub-hymenium** and outermost-layer of gill is

hymenium (fertile layer). In this layer, there are aseptate, club-shaped fertile cells called **basidia** and sterile paraphyses intermixed with basidia.

- Each basidium is having a dikaryon and at its maturity, two nuclei fuse to form a diploid nucleus. This diplophase in short-lived and diploid nucleus undergoes **R.D.** or meiosis to form 4 haploid nuclei (2 of + strain and 2 of – strain). Then 4 basidiospores are **exogenously** developed at the apex of each basidium (borne on outgrowths called sterigmata). The 4 basidiospores of a basidium are dispersed in rapid succession (by **water drop method**). These basidiospores germinate to give rise to + and – strain primary mycelia and thus life cycle is completed.

Mushroom cultivation

Mushrooms are rich source of vegetable **proteins** (21–30% proteins on dry wt. basis), **vitamins** (B, C, D and K) and **minerals** (Ca, Na, K, P, Fe), hence mushroom cultivation is done in different parts of India. For cultivation of *Agaricus bisporus* (button mushroom), following major steps are there—

(a) Composting (natural or synthetic compost).
(b) Spawning (dikaryotic mycelium or 'Spawn' contained in compressed blocks of richly manured compost acts as source of inoculum).
(c) Casing
(d) Picking and harvesting.

○ Most suitable temperature for growth of mushrooms is 30°–37°C.

LICHENS

- Lichens constitute a small and distinct group of plants having about **400 genera.**
- In lichens, there are 2 components; *i.e.*, **algal partner** called phycobiont and **fungal partner** called mycobiont.
- The term **lichen** was first given by **Theophrastus** for superficial growth on bark of *Olea europea* (olive) tree.
- Initially lichens were considered to be individual plants and were included in mosses but, **Schwendiner** (1867) gave **dual hypothesis**, *i.e.*, there are 2 components in lichen and defined lichens as **"fungi parasitizing algae"**.
- **Reininke** (1872) gave the term **consortium** for this association, *i.e.*, mutual growth and interdependence.
- **De Bary** (1879) gave this association the name **'symbiosis'**.
- **Crombie** (1885) gave the **master and slave hypothesis** for this association (also called husband and wife association) and in this association fungal partner is having upper hand. It is also known as **helotism** (most accepted association nowadays).
- Lichens have distinct structure different from algal and fungal partner.
- Lichens show **very slow growth.**

Habitat of lichens

They grow in varied habitats and can also grow in such habitats where other plants wouldn't grow, *e.g.*, **on bare rocks and in arctic region.** On the basis of habitat, lichens are of 3 types:

(1) **Saxicaulous lichens:** Which grow on rocks.
(2) **Corticaulous lichens:** Which grow on bark of trees.
(3) **Terricaulous lichens:** Which grow on earth crust.

○ Lichens **do not grow near big cities** because these are very sensitive to **air pollution** or smoke or specially **SO_2 pollution.**

Classification of lichens

(A) On the basis of fungal partner

Lichens are of 2 types:

1. **Ascolichens:** In which ascomycetes member is fungal partner.

These are further of 2 types:

(a) **Gymnocarpae:** Where fruiting body is **apothecium** type.
(b) **Pyrenocarpae:** Where fruiting body is **perithecium** type.

- Further in ascolichens, algal partner is mostly member of green algae and rarely blue-green algae.

2. **Basidiolichens:** Where basidiomycetes member is fungal partner. In them algal partner is generally **blue-green algae.**

In 80% cases algal partner is member of green algae or chlorophyceae and in 20% cases, blue-green algae or myxophyceae.

- Important members of green algae found in lichens are: *Trebauxia, Pleurococcus, Trentepohlia* and *Cladophora.*

Common blue-green algae are *Scytonema, Nostoc, Anabaena* and *Gleocapsa*, etc.

(B) Classification on the basis of structure of lichen thallus

Lichens are of 3 types:

1. **Crustose lichens:** These are present in the form of thick layer on the substratum and these cannot be separated without breaking them, *e.g., Graphic scripta, Rhizocarpon, Haematomma, Lecanora*, etc.
2. **Foliose lichens:** These are like dried leaves and are attached to substratum by special structures called **rhizinae**, *e.g., Parmelia, Physcia, Peltigera, Chaudhuria*, etc.
3. **Fruticose lichens:** These are like tiny or miny plants and attached to substratum by a disc. They may be **erect** (*e.g., Cladonia*) or **drooping** (*e.g., Usnea*).

(C) Classification on the basis of anatomy of thallus

1. **Homoiomerous:** Where algal and fungal partners are uniformly distributed throughout the lichen thallus. These are rare, *e.g., Collema* and *Leptogium.*
2. **Heteromerous:** Different zones as shown in figure are present here. These are common and most of the lichens are of this type. The different zones are upper cortex, algal zone, medulla and lower cortex.

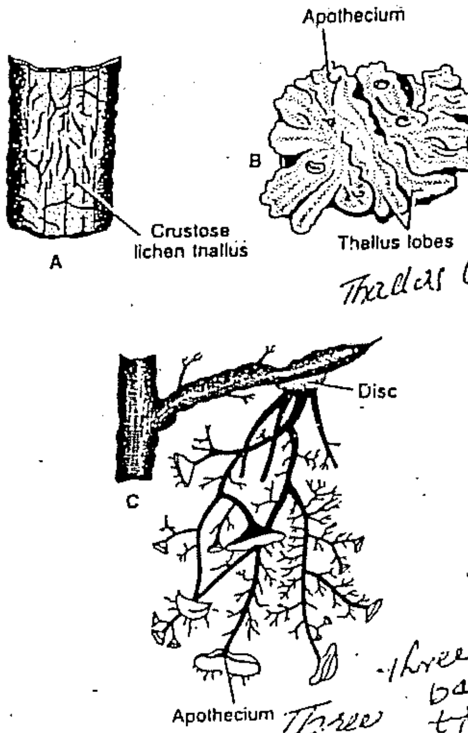


Fig. 11.12. Three basic types of lichens: A. Crustose B. Foliose C. Fruticose

Thallus lobes

of lichens -three basic types. Three

crustose

foliose.

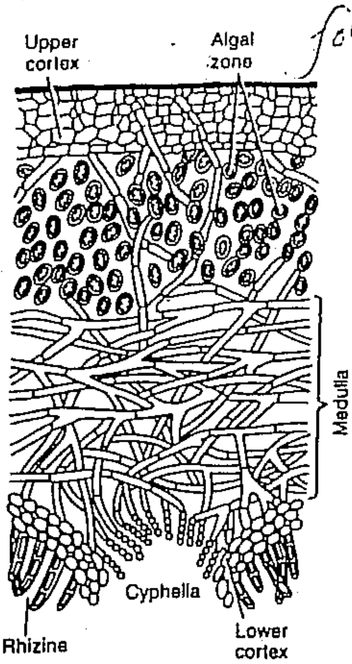


Fig. 11.13. V.S. of heteromerous lichen thallus passing through cyphella

Some special structures associated with lichen thallus

1. **Breathing pores:** Loosely arranged areas in upper cortex are breathing pores and they help in gaseous exchange.
2. **Cyphellae:** Loosely arranged areas in lower cortex are cyphellae and these also help in gaseous exchange.

- Cyphellae are analogous to stomata of higher plants.

3. **Cephalodia:** These are rounded outgrowths on the upper cortex surrounded by cortex. They contain different algal partner to that which is found in main lichen thallus. They retain moisture.
4. **Isidia:** Elongated outgrowths on upper cortex, containing same algal and fungal partners as are found in main lichen thallus. They increase the surface area of lichen and are means of vegetative reproduction.

Reproduction in lichens

1. **Vegetative reproduction:** By following methods—
   (a) **Fragmentation.**
   (b) **Isidia:** (See above).
   (c) **Soredia:** These are granular structures produced in large number at a particular patch of lichen thallus called **soralium.** Each soredium is having one or few algal cells surrounded by fungal hyphae.

2. **Asexual reproduction:** By formation of **pycnidiospores** or **pycniospores** which are produced inside **pycnidium** which is a flask-shaped structure, opening through a pore called **ostiole.**

The pycniospores come out through ostiole and on coming in contact with suitable algae form new lichen thalli.

3. **Sexual reproduction:** Sexual reproduction is a function of fungal partner.

Male sex organ is called **spermatogonium** which is just like pycnidium and inside it a number of non-motile sperms or **spermatia** are produced, which come out through ostiole. Female sex organ is **carpogonium** which is having lower coiled portion called **ascogonium** and upper straight portion coming out through upper cortex called **trichogyne.** The spermatia get attached to trichogyne and reach to the ascogonium and thus fertilization occurs.

Diploid ascogenous hyphae arise from ascogonium and terminal cell of each ascogenous hypha acts as ascus mother cell. Reduction division occurs in each ascus and 8 ascospores are formed in each ascus. Ascogenous hyphae, ascus mother cells, ascospores and some special sterile hyphae form fruiting body called **apothecium.**

- Ascospores are liberated from ascus and on coming in contact with suitable algae form new lichen thalli.

Economic importance of lichens

1. **As food and fodder:** *Cladonia rengiferina* (reindeer moss), found in Tundra region, is used as food or fodder for reindeer, musk ox, etc.

- *Parmelia* is used as food in South India. *Umbilicaria* is used as food in Japan, *Everina* is used for making bread in Egypt and *Lecanora* is used as delicious food in Israel. *Cetraria* (Iceland moss) is edible in Iceland.

2. Lichens as source of dyes:

- ○ **Litmus** (acid-base indicator) is obtained from *Roccella montaignei.*
- **Orchil** (blue dye) is obtained from *Cetraria, Roccella* and *Lecanora.*

3. Lichens as source of medicines: Medicinal property of lichens is due to a substance **lichenin.**

- **Usnic acid, an important broad spectrum antibiotic,** is obtained from *Usnea* and *Cladonia.*
- *Peltigera canina* is used against **hydrophobia.**
- *Xanthoria parietina* is used against **jaundice.**
- *Lobaria pulmonaria* is used against **lung infection.**
- *Cetraria* is used as **laxative.**

4. Lichens as soil formers: Lichens secrete some organic acids which break down rocks and thus help in soil formation.

5. Lichens as a source of cosmetics and perfumes: Some lichens having aromatic odour like *Everina* and *Ramalina* are used for manufacturing soaps. Some **sweet-scented thalli** are used for making Hawan Samagri, Dhoop, Agarbatti, etc.

6. Ecological importance: **Crustose lichens are pioneers in xerosere** (succession beginning in dry condition).

- **In xerosere, sequence of different stages is:**

$$\begin{tikzcd}
\underset{\text{(Pioneer)}}{\text{Crustose lichens}} \arrow[r] & \text{Foliose lichens} \arrow[d] \\
\underset{\text{(Climax)}}{\text{Trees}} & \text{Shrub stage} \arrow[l] & \text{Herb stage} \arrow[l] & \text{Moss stage} \arrow[l]
\end{tikzcd}$$

7. Lichens as indicators of SO_2 pollution: As lichens are very sensitive to air pollution, specially SO_2 pollution, so serve as indicator of air pollution (SO_2 pollution).

8. Poisonous lichens: *Cetraria juniperina* and *Letharia vulpina* (wolf moss) are used as poisons.

9. Lichens in brewing industry: **In Russia and Sweden,** some lichens like *Cetraria* and *Lecanora* are used for **alcoholic fermentation.**

Litmus is obtained from lichen.

$(C_7H_{11}NO_7)_n$

$(C_7H_{11}NO_2$

$C_{22}H_{54}N_4O_{21}$

MULTIPLE CHOICE QUESTIONS

1. Branch dealing with study of fungi is:
   (a) Phycology (b) Mycology
   (c) Mycetology [✓ (d) Both (b) and (c)]
2. Fungi differ from algae in that:
   (a) They are non-vascular
   (b) Sex organs unicellular and non-jacketed
   [✓ (c) No embryo formation]
   (d) Pseudoparenchyma present
3. As we move from lower to higher group in fungi, there is gradual .... of sexuality:
   (a) Reduction
   [✓ (b) Elaboration]
   (c) Sometimes reduction, sometimes elaboration
   (d) No change
4. Spontaneous creation theory was put forward by:
   (a) Magnus (b) Alexopaulus
   [✓ (c) Needham] (d) Ainsworth
5. Who started fungal studies in India?
   (a) Dastur (b) K.C. Mehta
   [✓ (c) E.J. Butler] (d) Sadasivan
6. Who is known as 'Father of Indian Mycology'?
   (a) K.C. Mehta (b) Mundkar
   [✓ (c) Butler] (d) Mukherjee
7. Who is not a mycologist?
   (a) K.C. Mehta (b) Mundkar
   (c) Desikachary (d) Srinivasan
8. Who is associated with study of annual recurrence of wheat rust in India?
   (a) Butler (b) Thind
   (c) Mehta (d) None of these
9. Which is known as 'Water Mould'?
   (a) *Monoblepharis* (b) *Saprolegnia*
   [✓ (c) Both (a) and (b)] (d) None of these
10. Which is a 'Coprophillous fungi'?
    (a) *Rhizopus* (b) *Mucor*
    (c) *Penicillium* [✓ (d) None of these]
11. 'Blue mould' is:
    (a) *Mucor* (b) Yeast
    (c) *Aspergillus* [✓ (d) *Penicillium*]
12. Which is commonly called 'Pin mould'?
    (a) *Penicillium* (b) *Aspergillus*
    [✓ (c) *Rhizopus*] (d) Yeast
13. Which of the following is not a 'predacious fungi'?
    (a) *Arthrobotrys* (b) *Zoophagus*
    [✓ (c) *Monobelpharis*] (d) *Dactylaria*
14. Fungi grow well:
    [✓ (a) At 20–30°C and acidic pH (about 6.0)]
    (b) At 30–40°C and pH 7.0 (neutral)
    (c) 10–20°C at alkaline pH (8.0)
    (d) 0–10°C, 5.0 pH
15. Unicellular, uninucleate fungus is:
    (a) *Penicillium* (b) *Rhizopus*
    [✓ (c) Yeast] (d) None of these
16. 'Dolipore septum' is characteristic of:
    (a) Myxomycetes (b) Phycomycetes
    (c) Deuteromycetes [✓ (d) Basidiomycetes]
17. Cell wall may be absent in some:
    (a) Slime moulds (b) Algal fungi
    (c) Fungi imperfectii (d) None of these
18. Cell wall in fungi is made of:
    (a) Cellulose (b) Starch
    [✓ (c) Chitin] (d) All of these
19. Molecular formula of chitin is:
    (a) $C_{55}H_{72}O_5N_4Mg$ (b) $(C_{12}H_{22}O_{11}N_2)_n$
    [✓ (c) $(C_{22}H_{54}N_4O_{21})_n$] (d) $(C_{22}H_{50}N_6O_{22})_n$
20. When fungal hyphae are interwined to form dense cord-like structures, they are called:
    (a) Plectenchyma (b) Sclerotia
    [✓ (c) Rhizomorph] (d) Pseudoparenchyma
21. Sexual reproduction by gametangial copulation occurs in: (AFMC 2002)
    (a) *Synchytrium* (b) Yeast
    [✓ (c) *Rhizopus*] (d) Both (b) and (c)
22. 'Sac fungi' are members of:
    (a) Phycomycetes (b) Basidiomycetes
    [✓ (c) Ascomycetes] (d) Deuteromycetes
23. Basidiomycetes class of fungi are called:
    (a) Sac fungi [✓ (b) Club fungi]
    (c) Algal fungi (d) None of these
24. Cup-like fruiting body (Ascocarp) of Ascomycetes is called:
    [✓ (a) Apothecium] (b) Perithecium
    (c) Cleistothecium (d) None of these
25. 'Clamp connections' are found in:
    (a) Phycomycetes (b) Ascomycetes
    [✓ (c) Basidiomycetes] (d) Deuteromycetes
26. 'Fairy rings' are associated with:
    (a) Rusts (b) Smuts
    [✓ (c) Mushroom] (d) Yeast
27. *Deuteromycetes are called 'Imperfect fungi' as:
    (a) They have no cell wall (b) No mycelium
    [✓ (c) No sexual reproduction] (d) All of these
28. Which is called 'Weed of Laboratory'?
    (a) *Rhizopus* (b) *Penicillium*
    [✓ (c) *Aspergillus*] (d) *Albugo*
29. Red bread mould (Red mould) is:
    (a) *Rhizopus* [✓ (b) *Mucor*]
    (c) *Neurospora* (d) *Morchella*
30. Which is commonly called 'Puff balls'?
    [✓ (a) *Lycoperdon*] (b) *Polyporus*
    (c) *Amanita* (d) *Peziza*
31. 'Earth star' is:
    (a) *Coprinus* [✓ (b) *Geaster*]
    (c) *Clavatia* (d) *Lycoperdon*
32. Which is called 'Birds nest fungus'?
    (a) *Polyporus* (b) *Claviceps*
    (c) *Geaster* [✓ (d) *Cyathus*]

33. Which is not an 'edible fungus'?
(a) *Agaricus* (b) *Morchella*
(c) *Clavatia* [✓ (d) *Amanita*]

34. First antibiotic obtained was:
[✓ (a) Penicillin] (b) Thiothricin
(c) Streptomycin (d) Chloromycetin

35. Penicillin (Wonder drug) is obtained from:
[✓ (a) *Penicillium notatum*] (b) *P. chrysogenum*
(c) Both (a) and (b) (d) None of these

36. 'Ergotine' is obtained from:
(a) *Penicillium* (b) *Clavatia*
[✓ (c) *Claviceps*] (d) *Agaricus*

37. An anticancer substance is obtained from a fungus?
(a) *Lycoperdon* (b) *Psaliota*
[✓ (c) *Clavatia*] (d) *Amanita*

38. Which fungus is used in baking as well as brewing industries?
(a) *Aspergillus* [✓ (b) Yeast]
(c) *Penicillium* (d) None of these

39. 'Invertase' enzyme is prepared from:
(a) *Aspergillus flavus* (b) *Saccharomyces cerevisiae*
(c) *Penicillium camemberti* (d) None of these

40. Which fungus is used in cheese industry?
(a) *Rhizopus* [✓ (b) Yeast]
(c) *Penicillium* (d) *Aspergillus*

41. Fungus used in genetic and biological studies is:
(a) *Neurospora* (b) Yeast
(c) *Ascobolus* [✓ (d) All of these]

42. Which is used as trace organisms (in detecting trace elements like Cu, Zn, Mo, etc.)?
(a) *Penicillium* [✓ (b) *Aspergillus*]
(c) *Rhizopus* (d) *Mucor*

43. Famous famine of Ireland (1845) was due to a disease produced by: **(AMU 1991)**
(a) *Alternaria* [✓ (b) *Phytophthora*]
(c) *Puccinia* (d) *Ustilago*

44. Severe famine of Bengal was due to a disease of rice, caused by: **(BHU 1995)**
(a) *Xanthomonas oryzae* [✓ (b) *Helminthosporium oryzae*]
(c) Tungro Virus (d) All of these

45. Red rot of sugar cane is caused by? **(Raj. PMT 2001; Orissa JEE 2003)**
[✓ (a) *Puccinia*] (b) *Albugo*
(c) *Ustilago* (d) *Colletotrichum*

46. Which of the human diseases is of fungal origin?
(a) Aspergillosis
(b) Ringworm
(c) Automycosis (Ear infection)
[✓ (d) All of the above]

47. Which is responsible for wood rot or destruction of timber?
(a) *Erysiphe* (b) *Lycoperdon*
[✓ (c) *Polyporus*] (d) None of these

48. Which is highly poisonous fungus, called 'Poison cup'?
(a) *Clavatia* [✓ (b) *Amanita*]
(c) *Polyporus* (d) *Geaster*

49. Aflatoxins are produced by:
(a) *Aspergillus flavus* [✓ (b) *A. fumigatus*]
(c) *Penicillium islandicum* (d) All of these

50. 'LSD' is obtained from: **(CPMT 1998; AFMC 2000; Kerala PMT 2003)**
(a) *Clavatia* (b) *Claviceps*
(c) *Amanita* (d) *Trichoderma*

51. Crozier formation occurs in:
(a) Basidiomycetes (b) Deuteromycetes
[✓ (c) Ascomycetes] (d) None of these

52. 'Toad stools' are:
(a) All mushrooms (b) Edible mushrooms
[✓ (c) Poisonous mushrooms] (d) None of these

53. Parasexuality in fungi was first of all discovered by: **(DPMT 2003)**
(a) Butler (b) Mundkar
(c) Ainsworth [✓ (d) G. Pontecorvo]

54. 'Heterothallism' phenomenon was first observed in Mucorales by:
(a) Magnus [✓ (b) Ropers and Pontecorvo]
(c) Blakeslee (d) Alexopoulos

55. *Rhizopus* is a .... fungus:
(a) Parasitic [✓ (b) Saprophytic]
(c) Both (a) and (b) (d) None of these

56. Mycelium of *Rhizopus* is:
(a) Unbranched coenocytic (b) Branched uninucleate
(c) Unbranched uninucleate [✓ (d) Branched coenocytic]

57. How many types of hyphae are present in *Rhizopus*?
[✓ (a) 1] (b) 2
(c) 3 (d) 4

58. Asexual reproduction in *Rhizopus* occurs by:
(a) Zoospores (b) Aplanospores
(c) Chlamydospores (d) Both (b) and (c)

59. The erect hyphae called sporangiophores in *Rhizopus* arise:
(a) Singly (b) 2 at a point
(c) In tufts (d) None of these

60. The mature zygospore in *Rhizopus* is:
(a) Single layered (b) 2-layered
(c) 3-layered (d) 5-layered

61. Species of *Rhizopus* are:
(a) Homothallic
(b) Heterothallic
(c) Mostly homothallic rarely heterothallic
(d) Mostly heterothallic rarely homothallic

62. Penicillin was discovered by: **(AIIMS 1993)**
(a) P. Eherlick (b) Robert Koch
(c) S. Waksman [✓ (d) Alexander Fleming]

63. Gill fungi is:
(a) *Peziza* (b) *Fusarium*
(c) *Synchytrium* [✓ (d) *Agaricus*]

*64. A fungus with hyphae containing nuclei from different genomes, the nuclei do not fuse but divide independently and simultaneously as new cells are formed is:
(a) Phycomycetes (b) Zygomycetes
(c) Deuteromycetes (d) Basidiomycetes

65. Fungi which grows on burnt wood are called?
(a) Coprophilous (b) Corticolous
[✓ (c) Xylophilous] (d) None of these

66. A common fungus pyrophyte or pyrrophytic fungus is:
(a) *Rhizopus* (b) *Aspergillus*
(c) *Pyronema* (d) None of these

67. 'Perfect stage' of fungus means:

(a) When fungi is perfectly healthy
(b) When it reproduces asexually
[✓ (c) When it reproduces sexually]
(d) None of the above

68. Yeast secretes an enzyme responsible for fermentation, is:
(a) Invertase [✓ (b) Zymase]
(c) Enolase (d) Dehydrogenase

69. Who used the term 'Lichen', first of all?
(a) Theophrastus (b) Aristotle
(c) Schwendiner (d) Reininke

70. 'Dual hypothesis' in lichens was given by:
(a) Reininke (b) De Bary
(c) Schwendiner (d) Crombie

71. Which association is mostly considered in lichens?
(a) Consortium [✓ (b) Symbiosis]
(c) Helotism (d) None of these

72. The lichens growing on rocks are called:
[✓ (a) Corticaulous] (b) Terricaulous
[✓ (c) Saxicaulous] (d) None of these

73. Lichens show:
[✓ (a) Very fast growth] (b) Fast growth
[✓ (c) Very slow growth] (d) Normal growth

74. Where will the lichens be absent?
(a) On bare rocks [✓ (b) Arctic regions]
(c) Villages [✓ (d) Big cities]

75. A common phycobiont in lichens is:
[✓ (a) *Trebauxia*] (b) *Microcystis*
(c) *Cetraria* (d) *Oedogonium*

76. The mycobiont in lichens is mostly:
[✓ (a) Ascomycetes fungus] (b) Basidiomycetes fungus
(c) Phycomycetes fungus (d) Slime moulds

77. Which of the following is not a crustose lichen?
(a) *Rhizocarpon* [✓ (b) *Lecanora*]
(c) *Parmelia* [✓ (d) *Haematomma*]

78. The foliose lichens are attached to substratum by means of: (Orissa JEE 2002)
[✓ (a) Roots] (b) Rhizoids
[✓ (c) Rhizinae] (d) None of these

79. The drooping on pendant fruticose lichen is:
(a) *Parmelia* (b) *Physcia*
(c) *Cladonia* (d) *Usnea*

80. Most of lichens are:
[✓ (a) Homoiomerous] (b) Heteromerous
(c) Both (a) and (b) (d) None of these

*81. Cyphellae in lichens are analogous to .... in higher plants:
(a) Palisade tissue (b) Mesophyll
(c) Bundle sheath (d) Stomata

82. Lichens reproduce vegetatively by:
(a) Fragmentation (b) Soredia
(c) Isidia [✓ (d) All of these]

83. Sexual reproduction in lichens is like:
(a) Algal partner (b) Fungal partner
(c) Intermediate (d) New type

84. Which lichen is known as 'Reindeer Moss'? (Raj. PMT 2001)
(a) *Cladonia rengiferina* (b) *Parmelia*
(c) *Everina* (d) *Roccella*

85. 'Litmus' is obtained from:
(a) *Lecanora* (b) *Cetraria*
(c) *Roccella* (d) *Parmelia*

86. A broad spectrum antibiotic produced by lichens is:
(a) Bacterin (b) Griseofulvin
(c) Usnic acid (d) Chlorellin

87. Lichens are most sensitive to:
(a) NO_2 pollution (b) SO_2 pollution
(c) CO pollution (d) O_3 pollution

88. Lichens are ecologically important as:
(a) They are association of algae and fungi
(b) They can grow in polluted area
(c) They are associated with mycorrhizal roots
[✓ (d) Earliest settlers on barren rocks]

89. Lichens are pioneers of vegetation in:
(a) Hydrosere (b) Halosere
(c) Psammosere [✓ (d) Lithosere]

90. Commercial production of citric acid is by:
(a) *Penicillium* [✓ (b) *Aspergillus*]
(c) *Rhizopus* [✓ (d) None of these]

91. Fungi are always: (MPPMT 2000; AFMC 2001)
(a) Autotrophs [✓ (b) Heterotrophs]
(c) Saprophytes (d) Parasites

92. Yeast is used in:
(a) Baking industry (b) Brewing industry
[✓ (c) Both (a) and (b)] (d) None of these

93. Common yeast generally reproduces by:
(a) Akinetes (b) Ascospores
(c) Aplanospores [✓ (d) Budding]

94. Yeast is an important source of: (CPMT 1993)
(a) Vit. C (b) Vit. B
(c) Vit. A (d) Vit. D

95. Yeasts are generally:
(a) Parasites (b) Epiphytes
[✓ (c) Saprophytes] (d) None of these

96. Reserve food materials of yeast are:
[✓ (a) Starch] (b) Proteins
[✓ (c) Carbohydrates and fats] (d) Oils and glycogen

97. Yeast is also known as:
(a) *Mucor* [✓ (b) *Saccharomyces*]
(c) *Ascomyces* (d) None of these

98. Yeast belongs to class: (CET Karnataka 2002; CPMT 2003)
(a) Phycomycetes [✓ (b) Ascomycetes]
(c) Zygomycetes (d) Deuteromycetes

99. Yeast grows more quickly in:
(a) Salt water (b) Bread
[✓ (c) Sugary solution] (d) Double Distilled water

100. The ascus of yeast contains:
[✓ (a) 10 ascospores] (b) 2 ascospores
[✓ (c) 4 or 8 ascospores] (d) 1 ascospore

101. Life cycle pattern of *Saccharomyces cerevisiae* is:
[✓ (a) Haplobiontic] (b) Diplobiontic
(c) Haplo-diplobiontic (d) None of these

*102. Pseudomycelium is characteristic feature of: (BHU 2002)
(a) Mushroom [✓ (b) *Mucor*]
(c) Bread mould [✓ (d) Yeast]

103. Which one is called 'Budding Yeast'?

(a) *Saccharomyces* (b) *Schizosaccharomyces*
(c) Both (a) and (b) (d) None of these

104. The budding in yeast is:
(a) Unipolar (b) Bipolar
(c) Unipolar or bipolar (d) None of these

105. Which one is absent from cell wall of yeast?
(a) Protein (b) Lipid
(c) Glucan and mannan (d) Cellulose

106. Copulation between two adjoining sister cells of yeast is called:
(a) Pedogamy (b) Adelphogamy
(c) Parthenogamy (d) Pseudogamy

107. Mycelium is the name given to plant body of:
(a) Algae (b) Fungi
(c) Bryophyta (d) Pteridophyta

108. In which fungus, columella is present in sporangium?
(a) *Rhizopus* (b) *Penicillium*
(c) Yeast (d) *Aspergillus*

109. The place from where bud is produced, a concave scar is formed on the yeast cell, which is called?
(a) Death scar (b) Birth scar
(c) Synscar (d) Neoscar

110. The yeasts were first of all reported by:
(a) Linnaeus (b) Pasteur
(c) Leeuwenhoek (d) Hooke

111. Which is incorrect for yeast?
[✓ (a) Saprophytic fungus] (b) Sexual reproduction present
[✓ (c) Sex organs present] (d) Causes fermentation

112. Dwarf strained yeast cells are:
(a) Oval, smaller and haploid
(b) Rounded, smaller and diploid
(c) Rounded, smaller and haploid
(d) Oval, larger and diploid

113. Roman king Claudius Caesar was murdered by his wife by giving him which fungus?
(a) *Lycoperdon* (b) *Amanita*
(c) *Agaricus* (d) *Morchella*

114. De Bary was a famous and leading:
(a) Pteridologist (b) Bryologist
(c) Mycologist (d) Phycologist

115. The conidiophores of *Albugo* are:
[✓ (a) Club-shaped and branched]
(b) Clavate and unbranched
(c) Peltate and branched
(d) Peltate and unbranched

*116. In *Albugo*, haploid chromosomes are not found in:
(a) Conidia (b) Hypha
(c) Coenocentrum (d) Oospore

117. Common form of food stored in a fungal cell is: **(BHU 1991)**
(a) Glycogen [✓ (b) Starch]
(c) Glucose (d) Sucrose

118. The female gametangium of ascomycetes is called:
[✓ (a) Ascogonium] (b) Cleistothecium
(c) Ascocarp (d) Perithecium

119. The *Albugo* resembles *Ulothrix* in:
(a) Food reserves (b) Unicelled gametangia
(c) Cellulosic cell wall (d) Uninucleate cells

120. Some species of *Mucor* show:
(a) Growth like fungus in aerobic condition and like yeast in anaerobic condition
(b) Growth like yeast in aerobic condition and like fungus in anaerobic condition
(c) Growth like yeast or fungus without any relationship
(d) Mycelial growth under aerobic and anaerobic conditions

121. *Saccharomyces cerevisiae* is: **(MPPMT 1999)**
(a) Akaryote (b) Prokaryote
(c) Mesokaryote (d) Eukaryote

122. Gills are seen in:
(a) Bacteria (b) *Oscillatoria*
(c) *Ulothrix* (d) *Agaricus*

123. Lichens participate in a:
[✓ (a) Xerosere] (b) Halosere
(c) Hydrosere (d) Psammosere

124. Mycorrhiza is a symbiotic relationship between higher plants and:
(a) Virus (b) Algae
[✓ (c) Fungi] (d) Bacteria

125. Gibberellin was first discovered from: **(DPMT 2001)**
(a) Algae [✓ (b) Fungi]
(c) Bacteria (d) Roots of higher plants

126. One of the common fungal diseases of man is:
(a) Plague [✓ (b) Ringworm]
(c) Cholera (d) Typhoid

127. Black rust of wheat is caused by: **(AFMC 1996; CBSE 2000)**
(a) Yeast (b) *Penicillium*
[✓ (c) *Puccinia*] (d) *Rhizopus*

128. Dicaryotic cells are formed in:
(a) Phycomycetes (b) Ascomycetes
(c) Basidiomycetes (d) In both (b) and (c)

129. In the production of leavened bread, the following is used: **(CPMT 1990)**
(a) Bacterium (b) Yeast
(c) *Rhizopus* (d) None of these

130. Fungi have been defined as chlorophyll less non-vascular plants by:
(a) Mundkar (b) Alexopoulos
(c) Bessey (d) Butler

131. *Rhizopus* belongs to the class: **(CPMT 1991)**
(a) Ascomycetes (b) Phycomycetes
(c) Basidiomycetes (d) Deuteromycetes

132. Fungi differ from algae in having:
(a) Cell wall made up of cellulose
[✓ (b) Cell wall of chitin and cellulose]
(c) Chlorophyll
(d) Starch as reserve food

133. Fungi imperfecti (Deuteromycetes) lack:
(a) Hyphae (b) Spores
(c) Asexual reproduction [✓ (d) Sexual reproduction]

134. White rust of crucifers is caused by: **(Raj. PMT 2002)**
(a) *Phytophthora* [✓ (b) *Albugo*]
(c) *Ustilago* (d) *Puccinia*

135. Yeast is abundantly found in:
(a) Organic substances rich in fats
[✓ (b) Organic substances rich in sugar]
(c) Moist bread
(d) Horse dung

136. Mushroom:
(a) Is a facultative parasite
(b) Is a saprophyte
(c) Is an obligatory parasite
(d) Photosynthesizes the food material

137. Most of lichens are composed of:
(a) Blue-green algae and basidiomycetes
[✓ (b) Blue-green algae and ascomycetes]
(c) Green algae and phycomycetes
(d) Green algae and ascomycetes

138. Which of the following disease is caused by a fungus?
[✓ (a) Tuberculosis]
[✓ (b) Black rust of wheat]
(c) Smallpox
(d) Cancer

139. All fungi differ from algae in: (CPMT 1989)
(a) Lacking chlorophyll and in having cell wall which is chitinized
(b) Being coenocytic
(c) Lacking unicellular forms
(d) Lacking motile ciliated gametes

140. A facultative parasite is one which:
(a) Is normally parasite but can also become a saprophyte
(b) Always requires dead organic matter
(c) Always requires a living host
(d) Is normally a saprophyte but can also become a parasite

141. Fungi producing usually 8 spores in a sac-like structure belong to:
(a) Basidiomycetes [✓ (b) Ascomycetes]
(c) Phycomycetes (d) Deuteromycetes

142. The plant body of *Albugo* is called:
[✓ (a) Mycelium] (b) Hymenium
(c) Hypha (d) Filament

***143.** Generally, in culture of *Rhizopus*, zygospores are not formed: (CPMT 1993)
(a) Due to lack of oxygen
(b) Due to shortage of light
[✓ (c) Due to absence of '+' and '–' strains]
(d) Due to presence of '+' and '–' strains

144. Yeast is unlike bacteria in being:
(a) Multicellular (b) Prokaryotic
[✓ (c) Eukaryotic] (d) Unicellular

***145.** The flagella on the zoospores of *Albugo* are:
(a) Unequal lateral (b) Equal lateral
(c) Unequal terminal (d) Equal terminal

146. Chlorophyll is absent in:
(a) *Nostoc* [✓ (b) *Rhizopus*]
(c) *Funaria* (d) *Cycas*

147. Sexual reproduction is absent in:
(a) Basidiomycetes [✓ (b) Deuteromycetes]
(c) Phycomycetes (d) Ascomycetes

148. All fungi are always:
[✓ (a) Parasites] (b) Autotrophs
[✓ (c) Heterotrophs] (d) Saprophytes

149. Which part of the plant is not affected by *Albugo*?
(a) Stem [✓ (b) Root]
(c) Leaf (d) Flower

150. The group of plants similar to animals in their requirements of oxygen for cellular respiration is:
(a) Lichens (b) Viruses
[✓ (c) Fungi] (d) Blue-green algae

151. The structure in which ascospores are formed is known as: (CPMT 1986)
(a) Basidium (b) Sporangium
[✓ (c) Ascus] (d) Gametangium

152. Nutritionally, *Albugo* is:
(a) Saprophyte (b) Facultative parasite
[✓ (c) Obligate parasite] (d) Facultative saprophyte

153. To digest food, the saprophytic fungi secretes:
[✓ (a) Enzymes] (b) Hormones
(c) Sugars (d) None of these

154. In yeast, meiosis occurs in:
(a) Zygote (b) Ascospores
[✓ (c) Ascus] (d) Pseudomycelium

155. The number of nuclei in a young basidium of *Agaricus* is:
[✓ (a) 1] (b) Many
(c) 4 (d) 2

156. Who is known as 'Father of Modern Mycology'?
(a) Waksman (b) Robert Koch
[✓ (c) Anton de Bary] (d) Micheli

157. Yeast is used in the production of:
(a) Acetic acid (b) Cheese
(c) Curd [✓ (d) Ethyl alcohol]

158. Sexual reproduction can occur in the absence of water in: (Raj. PMT 1990)
(a) *Ulothrix* (b) *Albugo*
(c) *Cycas* (d) Fern

159. *Penicillium* is economically important because it:
(a) Spoils food material
(b) Provides antibiotic drugs
(c) Causes pathogenic diseases
(d) Used in the preparation of alcohol

***160.** Roots of *Pinus* seedling are associated with:
(a) Fungus (b) Bacteria
(c) Algae (d) Microbes

161. Downy mildew disease is caused by:
(a) *Peronospora* (b) *Puccinia*
(c) *Albugo* (d) *Phytophthora*

162. Mycorrhiza is:
(a) A soil fungus
(b) A virus
(c) A symbiotic association of a soil fungus and the roots of *Pinus*
(d) None of the above

***163.** Yeast-like budding of oidia in *Mucor* is called:
(a) *Gongrosira* (b) *Torula*
(c) *Chantrasia* (d) *Palmella*

164. Which of the following is an edible fungus?
(a) *Mucor* (b) *Verticillium*
(c) *Agaricus* (d) *Fusarium*

165. Commercial source of manufacture of citric acid is: (BHU 1990)
(a) Citrus fruit (b) Bacteria
(c) *Aspergillus* (d) *Penicillium*

166. Yeast is not used in the manufacture of:
(a) Penicillin (b) Baking breads
(c) Toddy (d) Wine

167. Fairy rings are formed by:
(a) *Rhizopus* (b) *Batrachospermum*
(c) *Spirogyra* (d) *Agaricus*

168. The primary inoculum for white rust disease of crucifers is:
(a) Conidia (b) Mycelium in soil
(c) Oospores in the soil (d) Sporangia

169. How does the growth of *Albugo* affect its host?
(a) Kills it (b) Drains it
(c) Enriches it with nutrients (d) None of these

*170. Apothecial cups are found in:
(a) *Saccharomyces* (b) *Ascobolus*
(c) *Aspergillus* (d) All of these

171. A single mycelium of *Albugo* is capable of self-fertilization because it is:
(a) Dichogamous
(b) Monoecious
(c) Homothallic and self compatible
(d) Homothallic and self incompatible

172. Hyphal system is called mycelium in:
(a) Fungi (b) Pteridophytes
(c) Algae (d) Bryophytes

173. The mycelium is typically coenocytic in:
(a) Phycomycetes (b) Ascomycetes
(c) Basidiomycetes (d) None of these

174. Which of the following is famous mycologist of India?
(a) A.K. Sharma (b) T.S. Sadasivan
(c) M.O.P. Iyengar (d) P. Maheshwari

175. Which of the following produces non-motile gametes?
(a) *Ulothrix* (b) *Albugo*
(c) *Riccia* (d) *Pteridium*

176. Hypha in *Rhizopus* is:
(a) Multicellular (b) Ribbon-shaped
(c) Unicellular (d) Coenocytic

177. Bread mould is the common name of:
(a) *Batrachospermum* (b) *Rhizopus*
(c) *Agaricus* (d) *Bacillus*

178. Which of the following is fruiting body in *Penicillium*?
(a) Hypanthodium (b) Perithecium
(c) Cleistothecium (d) Apothecium

*179. Powdery mildew of crops is caused by:
(a) Ascomycetes (b) Basidiomycetes
(c) Phycomycetes (d) Bacteria

180. Which of the following is commonly called as blue-green mould?
(a) *Aspergillus* (b) *Erysiphe*
(c) *Penicillium* (d) *Neurospora*

181. Reproduction in *Mucor* takes place by:
(a) Anisogametes (b) Isogametangia
(c) Agametes (d) None of these

182. All heterotrophs require an environment which can provide:
(a) Organic compounds (b) Vit A
(c) Ammonium salt (d) Nitrates in solution

183. Gametangial copulation is common in:
(a) Ascomycetes (b) Zygomycetes
(c) Chytridiales (d) Deuteromycetes

184. *Rhizopus* is: (CPMT 1991)
(a) Autotrophic (b) Symbiotic
(c) Saprophytic (d) Parasitic

185. Which one of the following is not the mode of reproduction in yeast? (CPMT 1990)
(a) Budding (b) Fission
(c) Plasmogamy (d) Oogamy

186. The fruiting body in *Agaricus* is called:
(a) Pseudocarp (b) Pericarp
(c) Basidiocarp (d) Mesocarp

187. What is *Penicillium*?
(a) Virus (b) Algae
(c) Fungi (d) Bacteria

188. Motile sperms are absent in:
(a) Fern (b) *Cycas*
(c) *Funaria* (d) *Rhizopus*

189. Heating milk or any other liquid at 65°C and then sudden cooling is known as: (CPMT 1991)
(a) Sterilization (b) Pasteurization
(c) Preservation (d) Fermentation

190. *Albugo* causes:
(a) Downy mildews (b) Powdery mildews
(c) Rust (d) Smuts

191. Facultative saprophyte is:
(a) Always parasite
(b) Parasite but can be saprophyte
(c) Saprophyte but acquires a parasitic mode
(d) Always saprophyte

192. *Albugo candida*, the agent of white rust disease is a: (Raj. PMT 1992)
(a) Protist (b) Microbe
(c) Fungus (d) Prokaryote

193. The most economic method for controlling white rust of crucifers is:
(a) Soil fumigation (b) Crop rotation
(c) Use of fungicides (d) Use of antibiotics

194. Vegetative reproduction in yeast takes place by:
(a) Budding (b) Akinetes
(c) Aplanospores (d) Ascospores

195. When two host species are required for the completion of life cycle of a parasitic fungus, this condition is described as:
(a) Heteroecious (b) Heterokaryotic
(c) Autoecious (d) Autotrophic

196. Lichen is symbiotic relationship between algae and:
(a) Mosses (b) Fungi
(c) Bacteria (d) Protozoa

197. The rusts are serious diseases of our economic plants, the disease is caused by the fungi:
(a) *Puccinia* (b) *Agaricus*
(c) *Rhizopus* (d) *Ustilago*

198. Fungal hyphae penetrate hard cell walls of their hosts with the help of:
(a) Sugar exudates (b) Hormones
(c) Enzymes (d) Sharp tips

199. *Albugo* is:
(a) Obligate intercellular pathogen
(b) Intracellular parasite
(c) Intercellular saprophyte
(d) Facultative intercellular parasite

200. A fungus which requires only one single host for completion of its life cycle is called:
(a) Heterothallic (b) Heterosporous
(c) Autoecious (d) Heteroecious

201. Some haploid structures of *Rhizopus* include:
(a) Mycelia, sporangia and spores
(b) Hyphae, zygote and sporangia
(c) Mycelia, zygospore and spores
(d) Mycelia, zygospore and suspensor

202. The fruit juices turn bitter in taste if they are kept in open place for some time, because of:
(a) Bacteria of the atmosphere react with the juices
(b) Fermentation of the juice by yeast
(c) Some internal factors
(d) All the above three statements are correct

203. A lichen having a branching form and growing either prostrate or erect on the ground is called:
(a) Crustose (b) Foliose
(c) Thallose (d) Fruticose

204. Mycelium of *Albugo* is: (Raj. PMT 1990)
(a) Unseptate and multinucleate
(b) Unseptate and uninucleate
(c) Septate and uninucleate
(d) Septate and multinucleate

205. The bread is soft and porous when the yeast cells are mixed in the lump of wheat flour, because:
(a) Yeast produces benzoic acid
(b) Evolution of CO$_2$ makes the bread spongy
(c) Yeast is soft and flour also becomes soft
(d) Yeast produces acetic acid and alcohol which give softness to the bread

206. Lichens are the best indicators of:
[CPMT 1993; BCECE (P.T. Exam.) 2001]
(a) Water pollution (b) Soil pollution
(c) Air pollution (d) All of these

*207. Disease resistant plant varieties can be produced by:
(AFMC 1993)
(a) Heat treatment
(b) Colchicine treatment
(c) Hormonal treatment
(d) Crossing with wild varieties of plants

208. In a lichen, alga's partner is: (CPMT 1998)
(a) Any bryophyte (b) A fungus
(c) Any insect (d) A caterpillar

209. The flagella on the zoospores of *Albugo* are:
(a) Whiplash type
(b) Tinsel type
(c) One whiplash, one tinsel type
(d) Mixed type

210. In which of the following plants, columella is present in the sporangium?
(a) Yeast (b) *Spirogyra*
(c) *Ulothrix* (d) *Rhizopus*

211. Lichens reproduce by:
(a) Soredia (b) Gonidia
(c) Conidia (d) Oidia

212. Mycorrhiza is the: (Uttaranchal PMT 2001)
(a) Symbiotic association between fungus and the roots of seed plants
(b) Parasitic association between fungus and the roots of seed plants
(c) Saprophytic association between fungus and roots of seed plants
(d) All of the above

213. The process which the yeast cells perform is known as:
(a) Transpiration (b) Pasteurisation
(c) Fermentation (d) Effervescence

214. Haustorium of *Albugo* is:
(a) Knob like having only head
(b) Knob like having stalk and head
(c) Club-shaped
(d) Finger like

215. The yeast and *Penicillium* are included under:
(a) Phycomycetes (b) Ascomycetes
(c) Basidiomycetes (d) Myxomycetes

*216. Aeciospores of *Puccinia* are produced on:
(a) Lower surface of *Berberis* leaves
(b) Lower surface of wheat leaves
(c) Upper surface of wheat leaves
(d) Upper surface of *Berberis* leaves

217. Symbiotic associations of algae with fungi are found in:
(a) Mycorrhizal roots of *Pinus*
(b) Coralloid roots of *cycas*
(c) Lichens
(d) Gametophytes of *Lycopodium*

218. Late blight of potato is caused by:
(a) *Albugo candida*
(b) *Fusarium moniliforme*
(c) *Phytophthora infestans*
(d) *Alternaria solani*

219. Lichens show:
(a) Mycorrhizal relationship
(b) Commensalism
(c) Symbiosis of algae and fungi
(d) Parasitic relation of algae and fungi

220. Streptomycin was first isolated in 1944–45 by:
(a) Leeuwenhoek (b) Burkholder
(c) Alexander Fleming (d) Waksman

221. Approximately one hundred diseases and pests are reported on: (MPPMT 1994)
(a) Wheat (b) Gram
(c) Groundnut (d) Rice

222. *Albugo* reproduces asexually most commonly by:
(a) Zoosporangia (b) Aplanospores
(c) Conidiosporangia (d) Zygospore

223. The zygospore of *Mucor* is thick-walled and its colour is:
(a) Blue (b) White
(c) Green (d) Black

224. Best example of mutualism is:
(a) *Orchid* (b) *Cuscuta*
(c) *Lichen* (d) *Santalum*

*225. Penicillin is commercially obtained from:
(a) *Penicillium expansum*
(b) *Penicillium chryosogenium*
(c) *Penicillium divaricatum*
(d) *Penicillium claviforme*

226. Among of the following which one is an example of heterothallism?
(a) *Cycas* (b) Castor beans
(c) *Rhizopus* (d) *Pteris*

227. In diplobiontic life cycle of yeast the number of ascospores produced in an ascus is:
(a) Two (b) Four
(c) Six (d) Eight

228. First antibiotic isolated was:
(a) Terramycin (b) Neomycin
(c) Penicillin (d) Streptomycin

229. Lichens are the indicator of pollution:
(a) As they are sensitive to pollution
(b) As they flower well in polluted environment
(c) As they show association between algae and fungi
(d) As they grow faster than other plants

230. The fungal part of lichens generally belongs to the class:
(a) Phycomycetes (b) Ascomycetes
(c) Fungi Imperfecti (d) Basidiomycetes

231. Hypertrophy of floral parts in a cruciferous plants is caused by:
(a) Conidia of *Cystopus*
(b) Conidiophores of *Cystopus*
(c) Accumulation of hyphae of *Cystopus* for sexual reproduction
(d) All of the above

232. The reduction division in the life cycle of *Rhizopus* occurs: (CPMT 1990)
(a) At the time of germination of zygospore
(b) During the formation of germ sporangium
(c) During sexual reproduction
(d) During the formation of gametangium

233. Fusion between two morphologically similar but physiologically different thalli in fungi is known as: (CPMT 1990)
(a) Isogamy (b) Anisogamy
(c) Homothallism (d) Heterothallism

234. In yeast, during budding, which process occurs?
(a) Doubling of chromosomes
(b) Spindle formation
(c) Unequal division of cytoplasm
(d) Synapsis

235. Heterothallism was discovered by: (CPMT 1990, 92)
(a) Alexopoulos (b) K.C. Mehta
(c) Blakeslee (d) Louis Pasteur

236. Fungal filament systems is known as mycelium. Pseudomycelium is formed in:
(a) *Rhizopus* (b) Yeast
(c) *Puccinia* (d) *Synchytrium*

237. Yeasts are economically very important because they:
(a) Are used in tea and tobacco industry
(b) Are used in wine and baking industry
(c) Spread plant diseases
(d) Spread animal diseases

238. *Parmelia* belongs to:
(a) Fruticose lichens (b) Foliose lichens
(c) Crustose lichens (d) Liverworts

239. Aflatoxin was discovered in: (BHU 1991)
(a) *Penicillium* (b) *Rhizopus*
(c) *Aspergillus* (d) *Agaricus*

240. Heterothallism refers to: (CPMT 1992)
(a) Fusion is not accompanied with zygote formation
(b) Fusion between morphologically similar strain
(c) Fusion between the strains structurally similar and physiologically different
(d) All of the above

241. The vegetative cell of the *Saccharomyces* is recognised by the presence of:
(a) Chloroplasts
(b) A large vacuolated nucleus
(c) A small nucleus without a nuclear membrane
(d) A distinct cell wall

242. A group of algal cells imprisoned in fungal mycelium serving for vegetative multiplication of a lichen, is called:
(a) Isidium (b) Soredium
(c) Cephalodium (d) Helotism

243. If a bell jar is immediately placed over a slice of moist bread and observed after a few days:
(a) The bread swells
(b) Fungal mycelium develops
(c) Fungus does not develop
(d) Water drops occur inside the bell jar as bread respires

244. *Pythium debaryanum* is the causative agent of:
(a) Powdery mildew
(b) Black wart disease of potato
(c) Damping off of seedling
(d) Soft rot of sweet potato

245. Severe famine of West Bengal of 1942-43 was due to destruction of rice crop by a fungus called:
(a) *Penicillium* (b) *Helminthosporium*
(c) *Rhizopus* (d) *Puccinia*

246. Wart disease of potato is caused by: (MPPMT 1992)
(a) *Phytophthora infestans*
(b) *Synchytrium endobioticum*
(c) *Pythium debaryanum*
(d) *Peronospora destructor*

247. Dry Bordeaux mixture is:
(a) Insecticide (b) Herbicide
(c) Fungicide (d) None of these

248. Which of the following causes smut disease in cultivated plants?
(a) *Puccinia* (b) *Cystopus*
(c) *Ustilago* (d) *Agaricus*

249. Aflatoxin is produced by: (AIIMS 1997; CPMT 1997)
(a) Bacterium
(b) Virus
(c) Fungus *Aspergillus flavus*
(d) Nematode

250. Which of the following is a fungicide?
(a) Bordeaux mixture (b) DDT
(c) 2–4, D (d) None of these

251. Which of the following can cause a disease in human beings? (BHU 1992)
(a) *Rhizopus* (b) *Aspergillus*
(c) *Puccinia* (d) *Cystopus*

252. The important active ingradients of ergot causing ergotism are constituted by:
(a) Alkaloids (b) Nucleic acids
(c) Phenols (d) Antibiotics

253. Mucorales mostly live on substrates such as:
(a) Animal matter (b) Dung
(c) Decaying plant (d) All of these

254. The mass of hyphae constituting the thallus of the fungi is known as:
(a) Haustorium (b) Mycelium
(c) Rhizomorphs (d) None of these

255. Sexual reproduction is absent in:
(a) *Rhizopus* (b) Zygomycetes
(c) Ascomycetes (d) Deuteromycetes

256. Fungi that live on dead matter and are incapable of infecting living organisms are known as:
(a) Obligate parasites (b) Facultative parasites
(c) Obligate saprobes (d) None of these

257. When the entire thallus gets converted into one or more reproductive structures the condition is known as:
(a) Holocarpic (b) Eucarpic
(c) Both (a) and (b) (d) None of these

258. A living organism infected by a parasite is known as:
(a) Facultative saprobes (b) Host
(c) Obligate parasite (d) All of these

259. Mycorrhiza is: (CBSE 1996; PMET Punjab 2003; Jharkhand CECE 2003)
(a) A fungus parasitising root system of higher plants
(b) An association of rhizobium with the roots of leguminous plants
(c) A symbiotic association of plant roots and certain fungi
(d) An association of algae with fungi

260. Black rust of wheat is caused by: (AFMC 1996)
(a) *Rhizopus* (b) *Puccinia*
(c) Yeast (d) *Penicillium*

261. One of these is known as blue mould: (AFMC 1996)
(a) *Penicillium* (b) *Erysiphe*
(c) *Aspergillus* (d) *Peziza*

262. Penicillin is obtained from: (MPPMT 1997)
(a) *Aspergillus fumigatus* (b) *Penicillium chrysogenum*
(c) *Penicillium griseofulvum* (d) *Streptomyces griseus*

263. In *Mucor* sps., usually isogamy takes place between: (MPPMT 1997)
(a) Same strains (b) + and – strains
(c) Zygospores (d) Microspores

264. Antibiotics are generally secreted by:
(a) Fungi (b) Actinomycetes
(c) Cyanobacteria (d) Both (a) and (b)

265. Which of the following lichen is harmful?
(a) *Umbellicaria* (b) *Usnea*
(c) *Labaria* (d) *Cetraria*

266. Lichens are the pioneers in a:
(a) Lithosere (b) Halosere
(c) Hydrosere (d) Psammosere

267. To digest food the saprophytic fungi secretes:
(a) Sugar (b) Hormones
(c) Enzymes (d) None of these

268. Female gametangium of *Cystopus* is:
(a) Oogonium (b) Pistil
(c) Ascogonium (d) Archegonium

269. *Saprolegnia parasitica* causes the:
(a) Soft rot in rice (b) Skin rot in frog
(c) Soft rot in papaya (d) Salmon disease in fishes

270. Tikka disease occurs in: (EAMCET 1992)
(a) Rice (b) Sugar cane
(c) Groundnut (d) *Sorghum*

*271. The diseases produce by the fungus *Ustilago* are known as "Smuts" because: (CBSE 1994)
(a) The affected hosts become completely black
(b) They produce sooty masses of spores
(c) They parasitize cereals
(d) Their mycelium in black

272. 'Mycorrhizae' are useful for plants mainly due to their following attribute: (BHU 1994)
(a) Fixing atmospheric nitrogen
(b) Enhanced absorption of nutrients from soil
(c) Killing insects and pathogens
(d) Providing resistance against abiotic stresses

273. Zygospores are formed in: (MPPMT 1995)
(a) *Puccinia* (b) *Penicillium*
(c) *Alternaria* (d) *Mucor*

*274. Ray fungi are: (BHU 1995)
(a) Ascomycetes (b) Basidiomycetes
(c) Actinomycetes (d) Phycomycetes

275. In fungi, the food material is stored in the form of: (BHU 1994)
(a) Starch (b) Fructose
(c) Glycogen (d) Sucrose

276. Smut of maize is caused by: (CBSE 1995)
(a) *Ustilago avenae* (b) *Ustilago maydis*
(c) *Ustilago hordei* (d) *Ustilago nuda*

277. Among plants 'pheromones' are secreted by the cells of following plants for the given function: (BHU 1994)
(a) All plants for growth and development
(b) Yeast for facilitating mating
(c) All fungi for sexual reproduction
(d) *Rhizopus* for the formation of zygospore

278. *Claviceps purpurea* is the causal organism of: (CBSE 1994)
(a) Smut of barley (b) Ergotism of rye
(c) Powdery mildew of pea (d) Rust of wheat

*279. The person, who gave first systematic description of fungi was:
(a) Malpighi (b) Ainsworth
(c) Alexopoulous (d) Micheli

280. Which of the following is ectophytic parasitic fungi?
(a) *Erysiphe* (b) *Puccinia*
(c) *Pythium* (d) All of these

281. Which of the following is a unicellular fungus?
(a) *Synchytrium* (b) *Saccharomyces*
(c) *Mucor* (d) Both (a) and (b)

282. *Neurospora* is used in biochemical as well as genetical researches, because:
(a) Grows on simple medium
(b) Rapid growth and reproduction
(c) Easy analysis of progenies
(d) All of the above

283. Which of the following is responsible for deterioration of house-hold articles?
(a) *Rhizopus* (b) *Mucor*
(c) *Aspergillus* (d) All of these

284. Which of the following fungi stain the wood (do not destroy)?
(a) *Penicillium* (b) *Fusarium*
(c) *Polyporus* (d) Both (a) and (b)

285. Plectenchyma is a tissue composed of:
(a) Parenchyma
(b) Collenchyma
(c) Mycelial threads of fungi
(d) Tracheids of higher plants

286. Antibiotic flavicin is obtained from: (MPPMT 1999)
(a) *Aspergillus fumigatus* (b) *Aspergillus clavatus*
(c) *Streptomyces griseus* (d) *Streptomyces fradiae*

287. A delicious and nutritious edible fungus commonly called 'true morel' or 'sponge mushroom' is:
(a) *Agaricus* (b) *Clavatia*
(c) *Morchella* (d) All of these

288. Heterotrophic absorptive mode of nourishment is found in: (CBSE 1990)
(a) Algae (b) Fungi
(c) Bryophytes (d) Pteridophytes

289. Soft rot of sweet potato and leak disease of strawberries are caused by:
(a) *Ustilago* (b) *Rhizopus stolonifer*
(c) *Rhizopus arrhizus* (d) None of these

290. Homothallic species of *Rhizopus* is:
(a) *Rhizopus sexualis* (b) *Rhizopus stolonifer*
(c) *Rhizopus oryzae* (d) None of these

291. Which of the following is helobial yeast?
(a) *Schizosaccharomyces octosporus*
(b) *Saccharomycodes ludwigii*
(c) *Saccharomyces cerevisae*
(d) None of the above

292. Elongated structure on upper cortex of lichen, having same algal and fungal partners as in main thallus is:
(a) Soredium (b) Isidium
(c) Cephalodium (d) Cyphellae

293. Sweet scented lichen thalli used for making soaps, cosmetics are:
(a) *Everina* and *Ramalina* (b) *Peltigera* and *Lobaria*
(c) *Xanthoria* and *Physcia* (d) None of these

294. Which lichen is commonly known as 'Wolf moss'?
(a) *Cetraria* (b) *Xanthoria*
(c) *Letharia vulpina* (d) *Lobaria pulmonaria*

295. Mycotoxins, which bind with DNA and prevent transcription are?
(a) Lysergic acid (b) Trans-cinnamic acid
(c) Aflatoxins (d) None of these

296. According to Ainsworth, *Rhizopus* belongs to sub-division:
(a) Mastigomycotina (b) Zygomycotina
(c) Ascomycotina (d) Basidiomycotina

297. Which fungus is commonly known as 'dead man's finger' or 'stink horn'?
(a) *Geaster* (b) *Phallus*
(c) *Cyathus* (d) None of these

298. 'Lawyer's wig', a name is given to fungus:
(a) *Amanita* (b) *Coprinus*
(c) *Phallus* (d) *Clavatia*

299. 'Bracket fungi' is:
(a) *Polyporus* (b) *Coprinus*
(c) *Armillaria* (d) *Albugo*

300. A fungus, which is commonly called 'Honey mushroom' is:
(a) *Armillaria* (b) *Geaster*
(c) *Claviceps* (d) *Morchella*

301. Ultimate bottle shaped structures of conidiophores of *Penicillium* are known as:
(a) Sterigmata (b) Metulae
(c) Paraphysis (d) None of these

302. In fermentation of cheese, the fungus used is:
(a) *Aspergillus flavus* (b) *Penicillium camemberti*
(c) *Penicillium chrysogenum* (d) *Mucor mucedo*

303. Bracket fungi, puff balls and toad stools are included in:
(a) Phycomycetes (b) Ascomycetes
(c) Basidiomycetes (d) Deuteromycetes

304. Fungi of oomycota are called:
(a) Sac fungi (b) Club-fungi
(c) Toad-stools (d) Egg fungi

305. The blue mould on cheese is included in:
(a) Phycomycetes (b) Ascomycetes
(c) Basidiomycetes (d) Actinomycetes

306. Yeast is not used in preparation of:
(a) Wine (b) Bread in bakery
(c) Toddy (d) Penicillin

307. The fungus that causes huge economical losses of our timber resources is:
(a) *Puccinia* (b) *Polyporus*
(c) *Morchella* (d) *Aspergillus*

308. A chemical substance produced by one micro-organism that inhibits or destroys the growth of other micro-organism is called: (MPPMT 1995; AFMC 1996, 97)
(a) Antibiotic (b) Antibody
(c) Aflatoxin (d) Antiallergic

309. The fungus without mycelium is: (AMU 1996; Manipal 1997)
(a) *Puccinia* (b) *Phytophthora*
(c) *Rhizopus* (d) *Saccharomyces*

310. The 'witches broom' of legume is caused by:
(a) Virus (b) Bacteria
(c) Fungus (d) Mycoplasma

311. Apple scab disease is caused by:
(a) *Ustilago* (b) *Puccinia*
(c) *Erysiphe* (d) None of these

312. Common form of food stored in fungal cell is or in fungi the food material is stored in the form of: (BHU 1992, 94)
(a) Glucose (b) Sucrose
(c) Glycogen (d) Starch

313. Loose smut of wheat is caused by: (BHU 1991; CBSE 1994)
(a) *Ustilago tritici* (b) *Cystopus*
(c) *Puccinia* (d) *Aspergillus*

314. A widely but periodically occurring plant disease is called: (AMU 1991)
(a) Endemic (b) Epiphytotic
(c) Epidemic (d) Sporadic

315. Bordeuax mixture used extensively for treatment of plant diseases was discovered by: (BHU 1997)
(a) J.H. Millardet (b) Lister Jospelly
(c) Louis Pasteur (d) Beijerinck

*316. Scientist famous for his researches on the wheat problems in India: (BHU 1992)
(a) K.C. Mehta (b) Subramaniyam
(c) M.O.P. Iyengar (d) Desikachary

317. Aflatoxins are produced by: (MPPMT 2000)
(a) Bacteria (b) Fungi
(c) Viruses (d) Nematodes

318. Plasmogamy refers to: (AIIMS 1992, 97)
(a) The fusion of two haploid hyphae with simultaneous nuclear fusion
(b) The fusion of two haploid hyphae without simultaneous nuclear fusion
(c) Fusion of egg cell with sperm
(d) Fusion of sperm cell with polar nuclei

319. The symbiotic association between a fungus and a gymnospermic plant is known as:
(a) Ectomycorrhiza (b) Endomycorrhiza
(c) Commensalism (d) Helotism

320. Ergot is obtained from: (AFMC 1997; BHU 1997)
(a) *Claviceps purpurea* (b) *Rhizopus arrhizus*
(c) *Puccinia graminis* (d) *Ustilago tritici*

321. Apple scab disease is caused by: (BHU 1997)
(a) *Colletotrichum* (b) *Venturia*
(c) *Puccinia* (d) *Ustilago*

*322. On the stem and leaf sheaths of wheat, brown pustules are formed, fusing later to form bigger pustules are typical symptoms of disease caused by: (AMU 1996)
(a) *Puccinia graminis* (b) *P. recondita*
(c) *P. striformis* (d) *Ustilago tritici*

323. Algae like fungi belong to the class: (MPPMT 1997)
(a) Basidiomycetes (b) Deuteromycetes
(c) Ascomycetes (d) Phycomycetes

324. The fungus which causes black rust of wheat belongs to? (CET Chandigarh 1992)
(a) Phycomycetes (b) Basidiomycetes
(c) Ascomycetes (d) Deuteromycetes

*325. Phytoalexins are toxins like antifungal substances produced by the host as a defensive measure against infection are generally: (BHU 1997; DPMT 2003)
(a) Proteins (b) Lipids
(c) Glycoproteins (d) Phenolic compounds

326. Penicillin was discovered in the year: (AIIMS 1992)
(a) 1909 (b) 1919
(c) 1929 (d) 1939

327. When yeast ferments glucose the products are: (CBSE 1994, 97)
(a) Ethanol and CO_2 (b) Water and CO_2
(c) Ethanol and water (d) Methanol and CO_2

328. Organisms which usually live as parasites but can grow saprophytically in the absence of their hosts plants are called: (Pondicherry 1997)
(a) Obligate parasites (b) Facultative parasites
(c) Obligate saprophytes (d) Facultative saprophytes

329. In fungi in a dikaryon cell: (DPMT 1997)
(a) There are two dissimilar haploid nuclei in the same protoplasm
(b) There are two similar nuclei in the same protoplasm
(c) There are two diploid nuclei in the same cell
(d) There are diploid zygotes

330. Which of the following is an example of symbiosis? (BHU 1997)
(a) *Utricularia* (b) *Agaricus*
(c) Lichen (d) Mango

331. *Puccinia* forms: (CBSE 1998)
(a) Uredia and pycnia on barberry leaves
(b) Uredia and aecia on wheat leaves
(c) Uredia and telia on wheat leaves
(d) Uredia and aecia on barberry leaves

*332. The cell walls of bacteria and fungi have: (CPMT 1998)
(a) N-acetyl glucosamine (b) N-acetyl muramic acid
(c) Cellulose (d) Chitin

333. Lichens represent symbiotic relationship between: (AFMC 1998; Orissa JEE 2003; AMU 2003)
(a) Algae and fungi (b) Viruses and algae
(c) Algae and bacteria (d) Viruses and bacteria

*334. Lichens are used: (CBSE 1998)
(a) In controlling air pollution
(b) In re-vegetation of wastelands
(c) As indicators of geo-resources such as gold and copper
(d) As bioindicators for monitoring air and water pollution

*335. Wheat rust spreads from barberry to wheat plants by: (CPMT 1999)
(a) Uredospores (b) Teliospores
(c) Basidiospores (d) Aeciospores

336. Which of the following is correctly matched? (AIIMS 1999)
(a) Ringworm – fungus (b) Typhoid – virus
(c) Herpes – bacteria (d) None of these

337. Gibberellins were first discovered in fungal genus: (MPPMT 1999; Uttaranchal PMT 2001)
(a) *Mucor* (b) *Rhizopus*
(c) *Agaricus* (d) *Fusarium*

338. Yeast is an important source of: (MPPMT 1999)
(a) Vitamin-C (b) Riboflavin
(c) Sugars (d) Proteins

339. Which of the molecules listed below is a product of fermentation of glucose by yeast? (MPPMT 1999, 2000)
(a) $(C_6H_{10}O_5)_n$ (b) C_2H_5OH
(c) $C_6H_{12}O_6$ (d) CH_3OH

340. The micro-organism grown on molasses and sold as a food flavouring substance is: (MPPMT 1999)
(a) *Saccharomyces* (b) *Rhizopus*
(c) *Acetobacter* (d) *Lactobacillus*

341. Reserve food material (RFM) in fungi is: (CBSE 2000; MPPMT 2000)
(a) Glycogen (b) Starch
(c) Sucrose (d) Maltose

342. In *Rhizopus*, sexual reproduction occurs by: (CPMT 2000)
(a) Aplanospore
(b) Sporangiospores
(c) Conjugation between two different strains
(d) Hypnospores

*343. Mycelium of *Mucor* is: (MPPMT 2000)
(a) Septate and unicellular (b) Septate and multicellular
(c) Aseptate and uninucleate (d) Coenocytic

344. Adhesive pad of fungi penetrates the host with the help of: (CBSE 2001)
(a) Mechanical pressure and enzymes
(b) Hooks and suckers
(c) Softening by enzymes
(d) Only by mechanical pressure

345. After reproduction in *Rhizopus*, the stage formed is: (CPMT 2001)
(a) Zygospore (b) Ascospore
(c) Oospore (d) None of these

346. Brewer's yeast is rich in vitamin: (Manipal 2001)
(a) B_{12} (b) B_7
(c) B_9 (d) B_2

347. LSD is: (Manipal 2001)
(a) A narcotic obtained from *Papaver somniferum*
(b) A hallucinogenic obtained from *Claviceps purpurea*
(c) A drug obtained from *Erythroxylon*
(d) A drug obtained from *Acacia catechu*

348. Kingdom 'Mycota' includes: (Manipal 2001)
(a) *Penicillium* and cyanobacteria
(b) *Penicillium* and yeast
(c) Yeast and cyanobacteria
(d) None of the above

349. In *Rhizopus* if conjugation fails, gametangia behave as zygospore. It is called as: (AIIMS 2001)
(a) Conidia (b) Gametangia
(c) Parthenospore (d) Sporangiospore

*350. Various fungi are known to accumulate considerable quantities of divalent metal such as:
(a) Cadmium (b) Zinc
(c) Lead (d) All of these

351. Powdery mildews of crops are caused by: (AIIMS 2001)
(a) Bacteria (b) Ascomycetes
(c) Phycomycetes (d) Basidiomycetes

352. Cell wall of *Mucor* is made up of: (MPPMT 2001)
(a) Chitin (b) Cellulose
(c) Pectin (d) Mucilage

353. In which 'torula condition' is found? (MPPMT 2001)
(a) *Spirogyra* (b) *Mucor*
(c) *Riccia* (d) *Ulothrix*

354. Black rust of wheat is caused by: (BHU 2001; DPMT 2003; PMET Punjab 2003)
(a) *Phytophthora* (b) *Puccinia*
(c) *Ustilago* (d) *Pythium*

355. Which of the following divisions of fungi includes 'club fungi'? (BHU 2001)
(a) Zygomycota (b) Ascomycota
(c) Deuteromycota (d) Basidiomycota

356. In *Rhizopus*, if conjugation fails, then gametangia behave as zygospore called: (CPMT 2002; EAMCET 2002)
(a) Conidia (b) Gametangia
(c) Parthenospore (d) Sporangiospore

357. *Rhizopus* belongs to which of the following class? (CPMT 2002)
(a) Phycomycetes (b) Ascomycetes
(c) Zygomycetes (d) Deuteromycetes

358. The zygospore in *Rhizopus* develops into: (CET J&K 2002)
(a) Zygospore (b) Progametangium
(c) Promycelium (d) Gametangium

359. A group of fungi with septate mycelium in which sexual reproduction is either unknown or lacking is classified under: (JIPMER 2002)
(a) Phycomycetes (b) Deuteromycetes
(c) Ascomycetes (d) Basidiomycetes

360. Wart disease caused by *Synchytrium endobioticum* is found in: (JIPMER 2002)
(a) Cabbage (b) Potato
(c) Peas (d) Groundnut

361. A part of mushroom which comes out from the soil is called: (Raj. PMT 2001)
(a) Basidiocarp (b) Ascogonium
(c) Ascocarp (d) Pericarp

362. Which is a correct statement? (Raj. PMT 2001)
(a) Perithecium is fruiting body of *Aspergillus*
(b) Sexual reproduction in *Albugo* is oogamous
(c) Ascomycetes is known as club fungi
(d) Sexual reproduction in *Helminthosporium* is oogamous

363. A septum in eumycota fungi, bearing a complex pore is designated as a: (BHU 2002)
(a) Coenocyte (b) Septate hypha
(c) Dolipore septum (d) Secondary simple pore

364. Covered smut of sorghum is caused by: (BHU 2002)
(a) *Sphacelotheca sorghii*
(b) *Sphacelotheca cruenta*
(c) *Sphacelotheca reiliana*
(d) *Tolyposporium ehrenberghii*

365. Mycorrhiza acts as: (BHU 2002)
(a) Modified root
(b) Mechanical tissue for support
(c) Root hair in adverse condition
(d) Organism for vegetative propagation

366. Which of the following structures helps in respiration of lichens? (AIIMS 2002)
(a) Soredia (b) Cyphella
(c) Isidia (d) Cephalodia

367. *Aspergillus niger* produces: (AFMC 2002)
(a) Citric acid (b) Oxalic acid
(c) Gluconic acid (d) All of these

368. Which of the following does not secrete toxins during storage conditions of crop plants? (CBSE 2002)
(a) *Aspergillus* (b) *Penicillium*
(c) *Fusarium* (d) *Colletotrichum*

369. Which fungal disease spreads by seeds and flowers? (CBSE 2002)
(a) Loose smut of wheat (b) Corn smut
(c) Covered smut of barley (d) Soft rot of potato

370. An abnormal increase in the number of cells due to infection is called: (EAMCET 2002)
(a) Hyperplasia (b) Hypertrophy
(c) Hypoplasia (d) Necrosis

371. Sporangiospores of *Mucor* are: (MPPMT 2002)
(a) Haploid (b) Diploid
(c) Triploid (d) Polyploid

372. *Mucor* shows: (MPPMT 2002)
(a) Isogamy (b) Anisogamy
(c) Oogamy (d) None of these

373. Which of the following statements is correct? (Raj. PMT 2002)
(a) In *Agaricus*, gills produce basidiospores
(b) In *Aspergillus*, fruiting body is perithecium
(c) In *Funaria*, capsule represents gametophytic generation
(d) None of the above

374. Mushroom belongs to: (CPMT 2003)
(a) Ascomycetes (b) Basidiomycetes
(c) Phycomycetes (d) Zygomycetes

375. Anti-haemorrhagic ergot alkaloids are obtained from: (Orissa JEE 2003)
(a) *Cinchona* (b) Algae
(c) Bryophytes (d) Fungi

376. Fungi lacks: (DPMT 2003)
(a) Mitochondria (b) Ribosomes
(c) G. complex (d) ER

377. The deadliest mushroom is: (Kerala PMT 2003)
(a) *Agaricus* (b) *Amanita*
(c) *Pleurotus* (d) *Volvarella*
(e) None of the above

378. Which one of the following pairs is correctly matched? (AIIMS 2003)
(a) *Rhizobium*—Parasite in the roots of leguminous plants
(b) Mycorrhizae—Mineral uptake from soil
(c) Yeast—Production of biogas
(d) Myxomycetes—The disease ringworm

379. *Mucor* is a: (Manipal 2003)
(a) Facultative saprophytic fungus
(b) Saprophytic fungus
(c) Parasitic fungus
(d) None of the above

ANSWERS

1—d	2—d	3—a	4—c	5—c	6—c	7—c	8—c	9—c	10—b	11—d	12—c
13—c	14—a	15—c	16—d	17—a	18—c	19—c	20—c	21—d	22—c	23—b	24—a
25—c	26—c	27—c	28—c	29—c	30—a	31—b	32—d	33—d	34—a	35—c	36—c
37—c	38—b	39—b	40—c	41—d	42—b	43—b	44—b	45—d	46—d	47—c	48—b
49—d	50—b	51—c	52—c	53—d	54—c	55—c	56—d	57—c	58—d	59—c	60—d
61—d	62—d	63—d	64—d	65—c	66—c	67—c	68—b	69—a	70—c	71—c	72—c
73—c	74—d	75—a	76—a	77—c	78—c	79—d	80—b	81—d	82—d	83—b	84—a
85—c	86—c	87—b	88—d	89—d	90—b	91—b	92—c	93—d	94—b	95—c	96—d
97—b	98—b	99—c	100—c	101—c	102—d	103—a	104—c	105—d	106—b	107—b	108—a
109—b	110—c	111—c	112—c	113—b	114—c	115—b	116—d	117—a	118—a	119—b	120—a
121—d	122—d	123—a	124—c	125—b	126—b	127—c	128—d	129—b	130—c	131—b	132—b
133—d	134—b	135—b	136—b	137—d	138—b	139—a	140—d	141—b	142—a	143—c	144—c
145—a	146—b	147—b	148—c	149—b	150—c	151—c	152—c	153—a	154—c	155—d	156—c
157—d	158—b	159—b	160—a	161—a	162—c	163—b	164—c	165—c	166—a	167—d	168—c
169—b	170—b	171—c	172—a	173—a	174—b	175—b	176—d	177—b	178—c	179—a	180—c
181—b	182—a	183—b	184—c	185—d	186—c	187—c	188—d	189—b	190—c	191—b	192—c
193—b	194—a	195—a	196—b	197—a	198—c	199—a	200—c	201—a	202—b	203—d	204—a
205—b	206—c	207—d	208—b	209—c	210—d	211—a	212—a	213—c	214—b	215—b	216—a
217—c	218—c	219—c	220—d	221—a	222—c	223—d	224—c	225—b	226—c	227—b	228—c
229—a	230—b	231—c	232—b	233—d	234—c	235—c	236—b	237—b	238—b	239—c	240—c
241—b	242—b	243—b	244—c	245—b	246—b	247—c	248—c	249—c	250—a	251—b	252—a
253—d	254—b	255—d	256—c	257—a	258—b	259—c	260—b	261—a	262—b	263—b	264—d
265—c	266—a	267—c	268—a	269—d	270—c	271—b	272—b	273—d	274—b	275—c	276—b
277—d	278—b	279—d	280—a	281—d	282—d	283—d	284—d	285—c	286—a	287—c	288—b
289—b	290—a	291—b	292—b	293—a	294—c	295—c	296—b	297—b	298—b	299—a	300—a
301—a	302—b	303—c	304—d	305—b	306—d	307—b	308—a	309—d	310—c	311—d	312—c
313—a	314—b	315—a	316—a	317—b	318—b	319—a	320—a	321—b	322—a	323—d	324—b
325—d	326—c	327—a	328—d	329—a	330—c	331—c	332—a	333—a	334—b	335—d	336—a
337—d	338—b	339—b	340—a	341—a	342—c	343—d	344—a	345—a	346—d	347—b	348—b
349—c	350—d	351—b	352—a	353—b	354—b	355—d	356—c	357—c	358—c	359—b	360—b
361—a	362—b	363—c	364—a	365—c	366—b	367—d	368—d	369—a	370—a	371—a	372—a
373—a	374—b	375—d	376—b	377—b	378—b	379—b					

EXPLANATION OF SELECTED QUESTIONS (*)

27. Perfect stage in fungi means sexual stage and as there is no sexual reproduction in Deuteromycetes class, hence this class of fungi is called imperfect fungi.
64. Dikaryotic mycelium is present in Basidiomycetes.
81. Cyphellae in lichens are present on lower surface and are meant for gaseous exchange, so comparable to stomata of higher plants.
102. Rapidly cut buds in yeast form a filamentous structure called pseudomycelium.
116. Oospore formed after fertilization is diploid stage in *Albugo*.
143. *Rhizopus* shows heterothallism, *i.e.*, zygospore is formed between two oppositely strained hyphae (+ and –).
145. Zoospores in *Albugo* are reniform with two lateral unequal flagella (posterior is of whiplash type and anterior is of tinsel type).
160. *Pinus* shows mycorrhizal association.
163. Yeast-like budding of oidia occurs in sugary solution in *Mucor* and *Rhizopus* to form torula stage or condition.
170. Fruiting body or ascocarp in *Aspergillus* is completely closed (cleistothecium), in yeast no ascocarp and in *Ascobolus* cup-shaped ascocarp (Apothecium) is present.
179. Powdery mildew is caused by *Erysiphe*, which belongs to ascomycetes class of fungi.
207. Wild varieties are generally disease resistant.
216. Aeciospores in *Puccinia* are produced in inverted cup-like structure called aecium on lower surface of barberry leaves.
225. Penicillin was first discovered from *Penicillium notatum* but now it is obtained commercially from *P. chrysogenum*.
271. Smut means sooty (black powdery) mass.
274. Ray fungi belong to basidiomycetes class.
279. First systematic description of fungi was given by Micheli, father of mycology.
316. Dr. K.C. Mehta is associated with study of annual recurrence of wheat rust in India.
322. *Puccinia graminis* causes stem rust or black rust of wheat, whose symptoms appear on stem and leaf-sheaths.
325. Phytoalexins (plant antibodies formed against infection) are mostly phenolic compounds.
332. Chitin, present in cell wall of fungi, is polymer of N-acetyl glucosamine, which is also present in cell wall of bacteria.
334. Crustose lichens are first plants to grow on barren rocks or land.
335. Aeciospores produced on barberry (alternate host) infect wheat (primary host).
343. Mycelium in *Mucor* is aseptate and multinucleate (coenocytic) as in *Rhizopus*.
350. Fungi like *Aspergillus* act as trace organisms as they accumulate different divalent metals.

Collenchyma have Plasticity & Sclerenchyma have elasticity

12

Bryophyta

- Main characteristics of bryophytes
- Distribution and habitat of bryophytes
- Classification of bryophytes
- Characteristic features of different classes of bryophytes: Hepaticopsida, Anthocerotopsida and Bryopsida
- Importance of bryophytes
- Important points to remember
- Life cycle of *Riccia*
- Life cycle of *Funaria*

BRYOPHYTA

Bryophyta is a small group of plants including about 850 genera and nearly 24,000 species. On the basis of evolution bryophytes stand in between thallophyta (algae) and pteridophyta. Bryophytes are land inhabiting or terrestrial plants. They complete their vegetative phase on land but water is necessary for their reproductive phase, *i.e.*, for completion of life cycle. So bryophytes are known as **"Amphibians of plant Kingdom"**.

- **Hedwig** is called 'Father of Bryology'.
- **Shiv Ram Kashyap** (S.R. Kashyap) is known as 'Father of Indian Bryology'.

MAIN CHARACTERISTICS OF BRYOPHYTES

1. They stand between algae and pteridophytes from evolution point of view.
2. Bryophytes are mostly terrestrial plants except few aquatic genera (*Riccia fluitans, Fontinalis antipyretica*, etc.).
3. Water is necessary for act of fertilization, *i.e.*, biflagellated antherozoids swim across the film of water.
4. The main plant body is **Gametophytic** (n) which is independent and may be **thallose** (no differentiation in root, stem and leaves), *e.g., Riccia, Marchantia, Anthoceros*, etc., or **foliose** (having leafy axis), *e.g., Funaria* (Moss), *Sphagnum*, etc.
5. True roots are always absent in bryophytes and in place of roots, **unicellular** (*e.g., Riccia, Marchantia*) or **multicellular** (*e.g., Funaria*) rhizoids are present which perform the function of roots.
6. In bryophytes vascular tissues, *i.e.*, xylem and phloem are absent (both in gametophytic and sporophytic generation). So the name **Atracheata** has been given to bryophytes by **Oswald Tippo** (1942).
7. The sex organs are **multicellular** and **jacketed**, *i.e.*, a sterile layer of cells is present around the sex organs for protection.

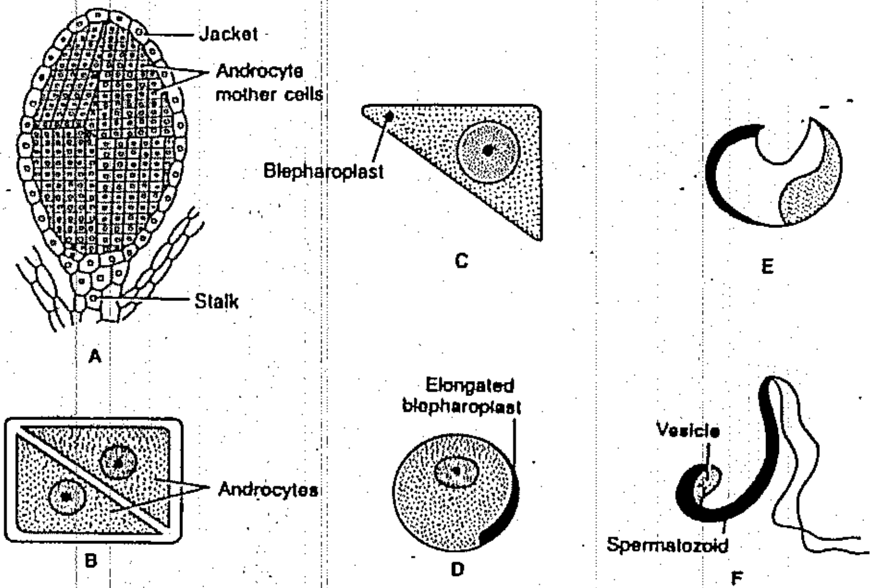


Fig. 12.1. A. Male sex organ (antheridium); B–F. Development of spermatozoid in bryophytes

8. Male sex organ is **antheridium**, which is somewhat rounded structure surrounded by single layered sterile jacket. Inside this jacket, there is mass of **androcyte mother cells**. Each androcyte mother cell divides diagonally to give rise to two androcytes and each androcyte gives rise to single coiled, biflagellated male gamete or spermatozoid or antherozoid.

   Female sex organ is **archegonium**, which is a flask-shaped structure having a swollen basal portion called **venter** (in which basal single egg cell and upper venter canal cell are present) and upper elongated portion, **neck** (in which variable number of neck canal cells are present). Later on the wall of venter divides periclinally to form a protective covering called **calyptra**.

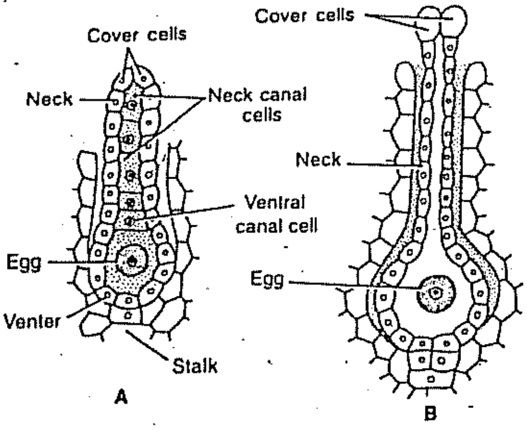


Fig. 12.2. Female sex organ (archegonium) in bryophytes: A. Young B. Mature

9. The sexual reproduction is of **oogamous type**, *i.e.*, fusion of a non-motile passive egg cell (female gamete) and biflagellated active male gamete (antherozoid).
10. The zygote divides at once without any resting period to form embryo and hence sporophyte or sporogonium.
11. The sporophyte or sporogonium is partially (*e.g.*, *Funaria*) or fully (*Riccia*) dependent upon the gametophytic generation.
12. The sporophyte or sporogonium is generally differentiated into foot, seta and capsule (although only capsule in *Riccia*).
13. Spores are produced inside capsule. Bryophytes are **homosporous**, *i.e.*, the spores are alike.
14. There is distinct alternation of generations, *i.e.*, **gametophytic phase** (n) starts with meiosis and ends with fertilization whereas **sporophytic phase** ($2n$) starts with fertilization and ends with meiosis.
15. In bryophytes there is progressive sterilization of sporogenous tissue as we move from lower to higher forms, *i.e.*, *Riccia* to *Funaria*.

DISTRIBUTION AND HABITAT OF BRYOPHYTES

Bryophytes are **cosmopolitan** in distribution. These are present in all such habitats or places where plants can occur. They are present in tropical and sub-tropical forests upto Arctic regions.

- ○ Probably bryophytes are not present in sea and Antarctica. In mountains, these are present upto the height of 18,000–20,000 ft.
- ○ *Aongstroemia julacea* is a bryophyte reported from maximum height, *i.e.*, at 19800 ft above sea level.

Bryophytes are mostly terrestrial plants, but a few are aquatic also, *e.g.*, *Riccia fluitans*, *Fontinalis antipyretica*, *Ricciocarpus natans*, *Riella* (only this member completes its life cycle fully under water).

Bryophytes generally grow in moist and shady places, *e.g.*, moist rocks, moist tree trunks, moist ground, etc. *Sphagnum* grows in boggy or marshy conditions. Besides, some of them grow in fully exposed sun conditions (xerophytic), *e.g.*, *Polytrichum juniperum*, *Tortula desertorum*, etc.

Some bryophytes grow as **epiphytes** on trunks of other plants, *e.g.*, *Dendroceros*, Acrogynous Jungermanniales and common moss *Porella*.

- ● Epiphyllous bryophyte *Radula protensa* occurs on fern fronds or leaves.

Most of them are *autotrophic*, but a few are **saprophytic**, *e.g.*, *Buxbaumia aphylla* and *Cryptothallus mirabilis*.

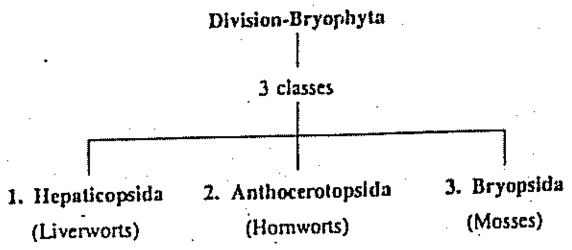
CLASSIFICATION OF BRYOPHYTES

The name bryophyta was first of all given by **Braun** (1864) to a group of plants, which included Algae, Fungi, Lichens and Mosses. **Schimper** (1879) gave the rank of division to this group **Bryophyta**.

Eichler (1883) divided bryophyta into two classes—**Hepaticae and Musci**. **Engler** (1892) divided Hepaticae into three orders, namely, **Marchantiales**, **Jungermanniales** and **Anthocerotales**. But **Underwood** (1894) recognized that Anthocerotales are quite different from Hepaticae and hence should be separated from Hepaticae.

Later on **Smith**, **Campbell** and **Schuster** divided Bryophytes into three classes—**Hepaticae**, **Anthocerotae** and **Musci**.

Rothmalir changed the name of three classes, *i.e.*, **Hepaticopsida**, **Anthoceropsida** and **Bryopsida**. **Proskauer** (1957) changed the name of **Anthoceropsida** to **Anthocerotopsida**.



CHARACTERISTIC FEATURES OF DIFFERENT CLASSES OF BRYOPHYTES

1. Hepaticopsida or Hepaticae

The members of this class are known as **'liverworts'** (*Hepatica*, liver) because the gametophytic plant body has liver like appearance.

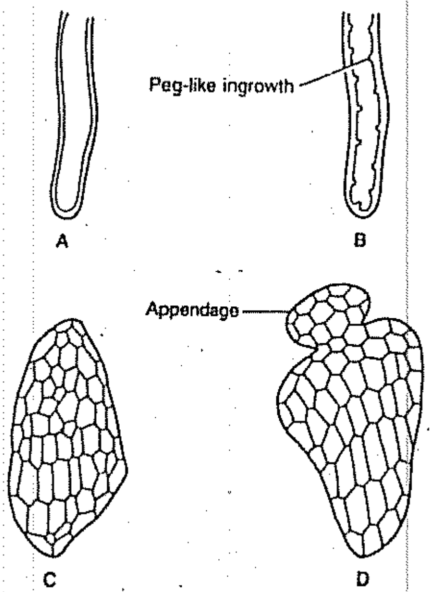


Fig. 12.3. Rhizoids and scales in Hepaticopsida: A. Smooth-walled rhizoid, B. Tuberculated rhizoid C. Ligulate scale, D. Appendiculate scale

Some of the important characters of this class are:

(i) The gametophytic plant body may be **thallose** (which is dorsiventrally differentiated and dichotomously branched), *e.g.*, *Riccia*, *Marchantia*, *Pellia*, etc., or foliose (in which leaves are arranged in 2–3 rows on the axis and leaves are without midrib), *e.g.*, *Fontinalis*, *Andreaea*, etc.

(ii) On the ventral surface of the thallus there are present **unicellular rhizoids** (which may be smooth-walled or tuberculated) and **multicellular** scales which may be **simple** (ligulate) or **appendiculate.**

(iii) Anatomically the thallus consists of upper (dorsal) assimilatory region having air pores and air chambers and the lower storage region.

(iv) Sex organs are present on dorsal surface of the thallus and develop from superficial cells.

(v) The sporophyte or sporogonium is differentiated into foot, seta and capsule.

(vi) Elaters are generally present but absent in some plants also, *e.g.*, *Riccia*. **The elaters have hygroscopic spiral thickenings which help in the dispersal of spores.**

(vii) The wall of the capsule is one to few layered without stomata and chlorophyll, hence **fully dependent upon gametophyte.**

(viii) Sporogenous tissue develops from **endothecium.**

(ix) Dehiscence of capsule is irregular.

- Important members are *Riccia*, *Marchantia*, *Sphaerocarpus*, *Pellia*, *Porella*, etc.

2. Anthocerotopsida or Anthocerotae

The members of Anthocerotopsida are commonly known as **'Hornworts'** because of typical horn-like appearance of their sporophyte or sporogonium. The important characters of this class are:

(i) The gametophytic plant body is thallose which is dorsiventrally differentiated and dichotomously branched.

(ii) On the ventral surface of the thallus, unicellular and smooth-walled rhizoids are present (tuberculated rhizoids and multicellular scales are altogether absent).

(iii) Anatomically, there is no differentiation of thallus into assimilatory and storage region. All the cells are alike having a single chloroplast. In each chloroplast single pyrenoid is present.

(iv) Sex organs are present on the dorsal surface of thallus.

(v) Antheridia or male sex organs develop from hypodermal cells and are present singly or in groups in antheridial cavities.

(vi) Archegonia develop from superficial cells and are embedded in the dorsal surface of thallus.

(vii) Sporophyte or sporogonium is horn-like and is differentiated into foot, short meristematic region and capsule.

(viii) Pseudoelaters are present in the capsule.

(ix) Sporogenous tissue develops from **amphithecium** and endothecium forms sterile central columella.

(x) The wall of the capsule is many-layered having stomata and some chlorophyll but still it is dependent upon gametophyte.

(xi) Dehiscence of capsule is irregular by means of longitudinal slits.

- Important members are *Anthoceros*, *Megaceros*, *Dendroceros* and *Notothylus*.

gametophyte-

3. Bryopsida or Musci

These are commonly known as **Mosses.**

Important characters of this class are:

(i) Gametophyte is differentiated into prostrate, branched, filamentous, thalloid **protonema** and leafy erect **gametophore.**

(ii) The main plant body, *i.e.*, leafy gametophore, is made up of axis having spirally arranged leaves. The leaves are with distinct midrib.

(iii) The rhizoids are multicellular, branched with oblique septa.

(iv) The sex organs develop from the superficial cells at the apex of leafy gametophore.

(v) Sporophyte or sporogonium is differentiated into foot, seta and capsule.

(vi) Elaters are absent in Bryopsida (Musci).

(vii) Sporogenous tissues develop from outer layer of endothecium while inner layer forms sterile columella.

(viii) The wall layers of sporophyte contain stomata for gaseous exchange.

(ix) Chlorophyll is present in the wall layers of sporophyte as a result of which sporophyte is partially dependent upon the gametophyte.

(x) Dehiscence is regular in Bryopsida.

- Important members are *Sphagnum, Polytrichum, Funaria,* etc.

VEGETATIVE REPRODUCTION IN BRYOPHYTES

Bryophytes show vegetative reproduction. The different methods are:

1. **By progressive death and decay of older portions of thallus:** This method is very common in thallose forms. When the decay reaches upto dichotomy, the two thalli are formed.
2. **By branch or thallus tips:** Under unfavourable conditions whole thallus disintegrates except the thallus tips, which on approach of favourable conditions give rise to new thalli, *e.g., Riccia.*
3. **By adventitious branches:** Some adventitious branches arise from the ventral surface of thallus and these on separation give rise to new thalli, *e.g., Riccia, Marchantia, Anthoceros,* etc.
4. **By tubers:** Under unfavourable conditions at the margins of thallus certain thick-walled tubers are formed which on approach of favourable conditions give rise to new thalli, *e.g., Anthoceros himalayensis.*
5. **By gemma:** In some bryophytes on dorsal surface, along midrib cup-like structures are found which are called gemma cups. Inside these gemma cups, multicellular bodies called **gemmae** are formed. Each gemma gives rise to two thalli, *e.g.,* most common in *Marchantia.*
6. **By primary protonema:** Spores on germination give rise to primary protonema which breaks up into a number of segments. Each segment develops buds from which leafy gametophores arise.
7. **By secondary protonema:** When protonema is formed from other structures (*e.g.,* from rhizoids, etc.) other than spores, it is called secondary protonema. It breaks into many segments and each gives rise to leafy gametophores.

IMPORTANCE OF BRYOPHYTES

1. Bryophytes are more important ecologically than economically as they grow on barren rocks after **crustose** and **foliose lichens,** *i.e.,* they help in completing ecological succession beginning on rocks (Lithosere). Bryophytes (mosses) constitute third seral stage in lithosere. The important mosses in this stage are *Polytrichum, Tortula* and *Grimmia.* They break down rocks and increase the soil layer and organic matter, as a result of which condition becomes suitable for next seral stage, *i.e.,* herbs.

   Sphagnum moss grows luxuriantly with other plants in muddy or boggy conditions and forms a dense mat or carpet. People are mistaken as if it is solid ground, so they constitute **Quacking bogs.** After the decomposition the bog turns into semisolid and solid places which are suitable for mesophytic vegetation.
2. **In preventing soil erosion:** Some bryophytes specially mosses form carpet vegetation, which bind soil particles and hence prevent soil erosion.
3. **In control of floods:** Huge amount of water is stored by some bryophytes and thus help in controlling floods, *e.g., Sphagnum,* etc.
4. **As packing material:** Some bryophytes, *e.g., Sphagnum* and other mosses are used as packing material for fragile goods, glasswares, standard quality crockery, etc.
5. **In nursery beds:** Because of the property of conserving moisture for a long time, these are used as packing material for cuttings, seedlings, etc.
6. In the preparation of moss sticks.
7. *Sphagnum* maintains acidity, so the fields where it is present, are suitable for the growth of acid-loving plants, *i.e.,* **oxylophytes.**
8. **Antiseptic absorbent bandages:** Some bryophytes have antiseptic properties, so they are used as bandages on wounds, *e.g., Sphagnum.*
9. **As fuel:** The partially decomposed *Sphagnum* moss accumulates to form compressed mass called **peat,** which after drying is used as coal.

○ The most economically important bryophyte is *Sphagnum.*

IMPORTANT POINTS TO REMEMBER

1. The smallest bryophyte is *Zoopsis argentea* belonging to order Acrogynous Jungermanniales (Hepaticae) and male thallus of *Buxbaumia aphylla* which measure only few mm.
2. Largest bryophytes are *Dawsonia superba* (upto 50 cm in height) and *Fontinalis antipyretica* (50–70 cm).
3. *Riccia* (Hepaticae) was named in honour of a florentine politician **P. F. Ricci.**
4. The name *Marchantia* was given in honour of **Nicolas Marchant,** the director of botanical garden Gaston d'orleans, Bloir, France.
5. *Pellia* (Jungermanniales) was named in honour of **Leopoldo Pelli-fabroni,** a lawyer of Florence, Italy who was the friend of **Raddi,** the discoverer of *Pellia.*
6. *Funaria* is called as **common moss or green moss or cord moss.**
7. *Sphagnum* is also known as **Peat moss, Turf moss or Bog moss.**
8. Largest thalloid bryophyte is *Monoclea forsteri* which is 20 cm in length and 5 cm in width.
9. *Polytrichum* is commonly called **Hair cap moss.**
10. *Pogonatum* is commonly called **Golden maiden-hair moss.**

11. Largest archegonium of plant kingdom is present in *Funaria.*
12. Oldest fossil bryophyte *Hepaticites* was first described by Walter (1925) from upper **carboniferous period.**

RICCIA

Systematic position

Division — Bryophyta
Class — Hepaticopsida
Order — Marchantiales
Family — Ricciaceae
Genus — *Riccia*

Riccia includes about 200 species and about 30 species have been reported from India. Most of the species are **terrestrial** (on damp soils) except *Riccia fluitans,* which is **aquatic in** nature.

- *Riccia himalayensis* (*R. discolor*) is the most common Indian species, which is present in plains and also upto height of 9,000 ft above sea level. It occurs during july to october. The plants show **rossette habit** on damp soil.

Other common Indian species are: *R. gangetica* (**endemic** to India), *R. frostii, R. melanospora, R. crystallina* (*R. robusta*) : it grow upto height of 14,000 ft a.s.l. and *R. fluitans,* which is only aquatic species and it occurs either **free floating** or **submerged** in stagnant pools, ponds and lakes of Kashmir, Garhwal, Chennai and Punjab.

Plant body

The main plant body of *Riccia* is **gametophytic** (n), which is thallose, *i.e.*, having no true roots, stem and leaves. Further the thallus is small, prostrate, dorsiventrally differentiated dichotomously branched and dark green in colour. The thalli are present in the form of patches called **rossettes.** The dorsal surface of thallus is smooth and shows **mid-dorsal groove,** whereas the ventral surface is having **unicellular rhizoids** and **multicellular scales.** The rhizoids are present along the midrib and are meant for absorption of water and nutrients from the substratum. The rhizoids are of 2 types—**smooth-walled** and **tuberculated.** The former are having smooth inner wall whereas later are having peg-like infolding (tubercles). The scales are violet coloured (due to **anthocyanins** in their cell sap) multicellular and one celled thick. These are present in **one row** towards apex of thallus and in 2 rows in portion away from the apex. The scales are **simple-ligulate** type and protect the growing point, which is situated in apical notch of the thallus. Further they help in conservation of water. In *R. crystallina,* scales are altogether absent. In *R. fluitans* (aquatic sps.), both rhizoids and scales are absent.

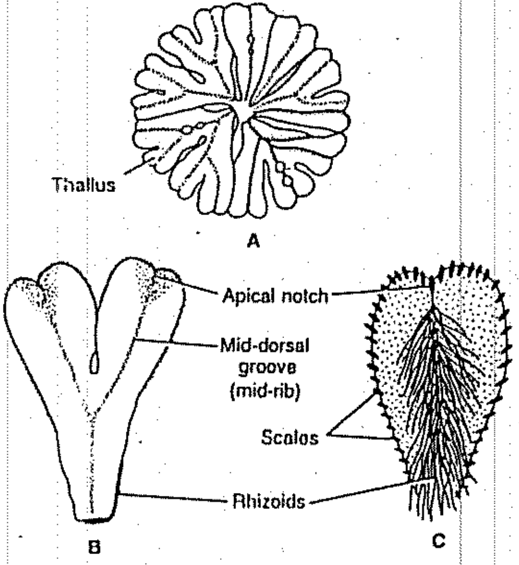


Fig. 12.4. *Riccia*: A. Rossette habit B. Dorsal view of thallus C. Ventral view of thallus

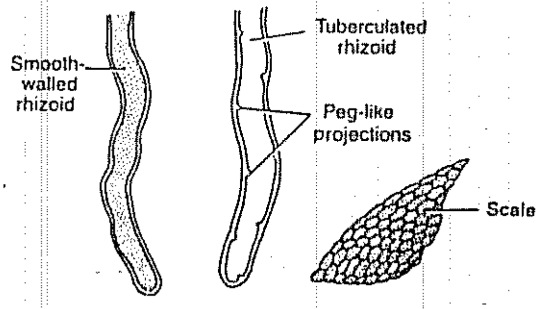


Fig. 12.5. Rhizoids and scale of *Riccia*

Anatomy of thallus

In vertical transverse section of thallus, two distinct regions are present, *i.e.*, upper or dorsal assimilatory or **photosynthetic region** and lower or ventral **storage region.**

The photosynthetic region consists of vertical rows of chlorophyllous cells with discoid chloroplasts called photosynthetic or **assimilatory filaments.** The terminal cell of each photosynthetic filament is devoid of chloroplasts, which constitute ill-defined **upper epidermis.**

In between these photosynthetic filaments, there are regular **air chambers,** which open outside through **air pores,** formed by terminal colourless cells of photosynthetic filaments. The air chambers help in gaseous exchange. This region is assimilatory in function.

The lower or ventral surface of thallus constitute colourless **storage region,** which is made of compact, parenchymatous cells without intercellular spaces. The cells of this region are filled with **starch grains.** The lower most layer of this region

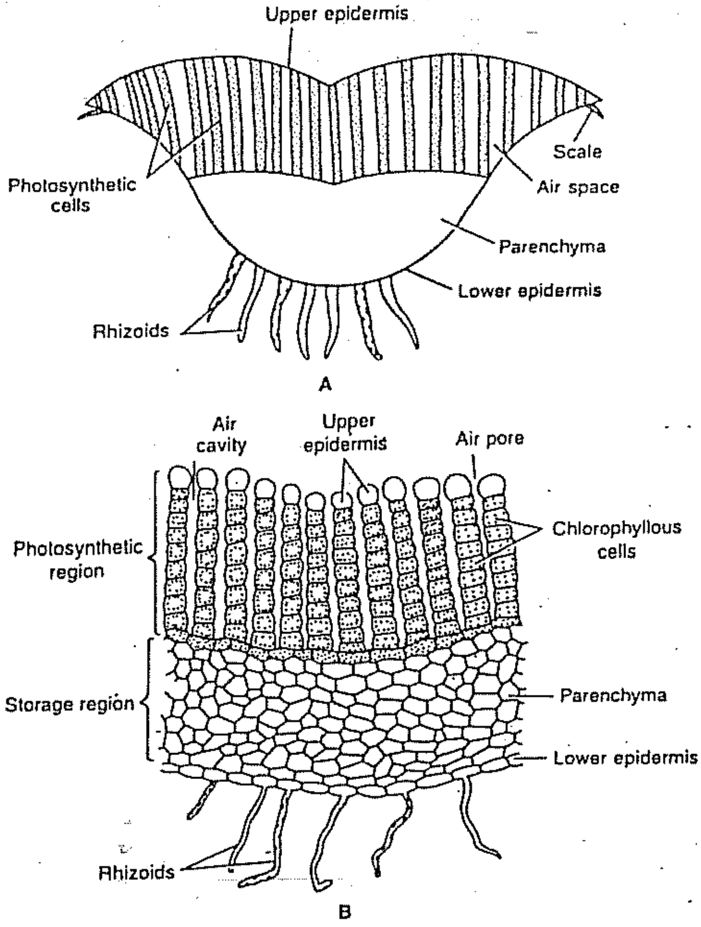


Fig. 12.6. A. A V.T.S. of *Riccia* thallus B. A portion magnified

is made of smaller and regularly arranged cells, which constitute **lower epidermis**, which gives rise to many smooth walled and tuberculated, unicellular rhizoids and multicellular scales.

Internal structure of aquatic species, *i.e.*, *Riccia fluitans* also shows **upper photosynthetic** and **lower storage** regions. But here, the photosynthetic zone is made of irregularly arranged, polyhedral air chambers, which are separated by one celled thick chlorophyllous cells. The upper epidermis is continuous without air pores. The storage region is made of few-cells, which is having lower epidermis on its lower side. The rhizoids are absent.

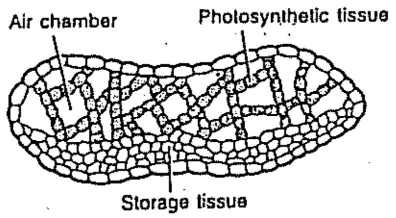


Fig. 12.7. Internal structure of *Riccia fluitans* thallus

Reproduction

Riccia reproduces by both vegetative and sexual method.

1. Vegetative reproduction

Occurs by following methods:

(a) **By progressive death and decay of older portions of thallus:** This is most common method of vegetative reproduction in *Riccia*. Here, there occurs progressive death and decay of older posterior portion of thallus and when this decay reaches upto dichotomy, the two thalli are formed.

(b) **By adventitious branches:** In some species, some special adventitious branches arise from ventral surface of thallus, which on separation, give rise to new *Riccia* thalli, *e.g.*, in *R. fluitans*.

(c) **By persistent thick apices:** The thallus apices grow downwards into the substratum and become thickened in prolonged dry season. These thick apices tide over unfavourable dry conditions and give rise to new thalli on approach of favourable conditions, *e.g.*, in *R. himalayensis*.

(d) **By tubers:** In some species, thick-walled **perennating tubers** develop at the apices of the thallus, which tide over unfavourable conditions and on approach of favourable conditions give rise to new thalli, *e.g.*, in *R. himalayensis, R. perennis*.

(e) **By gemmae:** Multicellular gemma-like structures are formed by cell division of young rhizoids, which give rise to new thalli **(Campbell, 1918).**

2. Sexual reproduction

Sexual reproduction is **oogamous** type in *Riccia*. **Antheridia** and **archegonia** are the male and female sex organs respectively. Most of the species are **monoecious** or homothallic, *i.e.*, male and female sex organs are present on the same thallus. A few species are **dioecious** or heterothallic, *i.e.*, antheridia and archegonia are present on different thalli. Common dioecious species of *Riccia* are *R. himalayensis* and *R. frostii.*

The sex organs are produced singly on mid-dorsal groove of *Riccia* thallus in **acropetal succession,** *i.e.*, oldest at the base and youngest at the apex. Antheridia and archegonia are present singly in **antheridial cavities** and **archegonial cavities** respectively. In homothallic species, antheridia are produced earlier than archegonia.

Antheridium (Male sex organ): Mature antheridium is

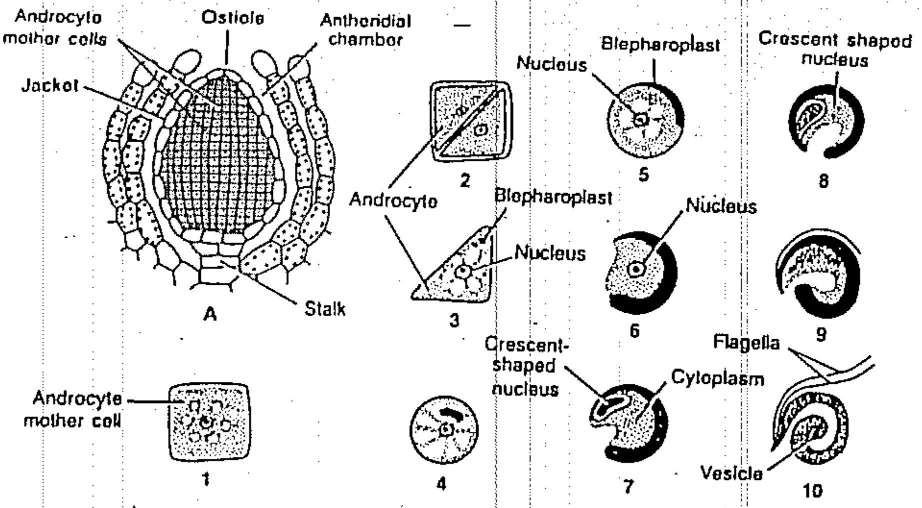


Fig. 12.8. A. Structure of antheridium and development of antherozoid in *Riccia* (1–10)

present inside antheridial cavity which opens on dorsal surface of thallus through a pore, called ostiole. Antheridium is having short **multicellular stalk,** which attaches antheridium at the base of antheridial cavity. The upper portion is main body of antheridium, which is having conical apex. The main body is surrounded by a single layered sterile jacket, inside which is compactly arranged mass of **androcyte mother cells.** Each androcyte mother cell divides diagonally to form **two androcytes,** each of which is metamorphosed to anteriorly biflagellated coiled **antherozoid** or **spermatozoid.** Sometimes, unused cytoplasm is present at the posterior end in the form of a vesicle.

The water enters into the antheridial cavity through ostiole. The jacket of antheridium disorganizes to form gelatinous mass. The antherozoids come out along with gelatinous mass through pore (ostiole) on dorsal surface of thallus, which swim in film of water on dorsal surface of thallus.

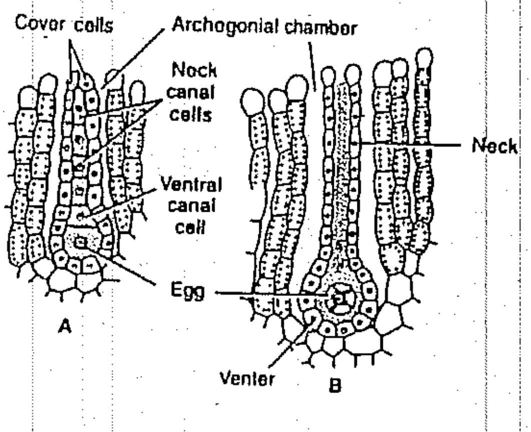


Fig. 12.9. Structure of archegonium of *Riccia* A. mature B. Just before fertilization

Archegonium (Female sex organ): Mature archegonium is present inside archegonial chamber, which is embedded on the dorsal surface of thallus and it opens by a pore. Mature archegonium is a **flask shaped** structure, which is attached by means of a **short stalk** to the thallus. It is having basal swollen portion called **venter** and upper elongated **neck.** The neck slightly projects out of surface of thallus. The venter is having large basal **egg** cell and upper smaller **ventral** or **venter-canal** cell. Further there is single layered jacket around venter, which is 12-20 cells in perimeter. The neck is having **neck canal,** which is having **4-6 neck canal cells.** There are 4 **cover** or **lid cells** at the apex of neck canal. Further, there are 6 vertical rows of cells around the neck and each row is 6–9 cells in height.

Fertilization

Water is necessary for act of fertilization. Before fertilization, **neck canal** cells and **ventral canal** cell disorganize to form **mucilaginous** mass, which absorbs water and swells up, exerts pressure as a result of which the cover cells at the top of neck separate apart to form opening, through which mucilaginous mass oozes out. The biflagellated antherozoids are attracted towards the neck of archegonium **chemotactically** due to presence of some **soluble proteins** and **potassium** ions in mucilaginous mass oozing out of the neck of archegonium. The antherozoids swim through film of water and reach to the neck of archegonium. Many antherozoids may enter into the archegonium, but only one of them is able to fuse with single egg to form **zygote** ($2n$), which is beginning of sporophytic phase.

The Sporophyte

Soon after formation of zygote, it enlarges in size and fills up the cavity of venter. The zygote also secrets a wall around it.

- The wall of the venter divides by a **periclinal** division to form 2 layered **calyptra** (protective covering of sporophyte).
- Without any resting period, enlarged zygote undergoes first **transverse division** (at right angles to **neck** of archegonium), which is followed by a **vertical division,** thus forming 4-celled (Quadrant) stage of embryo. These 4 cells now divide irregularly to form 20-40 cells. Now

there occurs periclinal division in superficial cells of this mass to form outer single layered **amphithecium** and inner mass of cells called **endothecium**.

- The amphithecium after anticlinal divisions give rise to **sterile jacket** of sporophyte or sporogonium.
- The cells of endothecium after repeated divisions give rise to **sporogenous tissue** and hence **spore mother-cells**. Each spore mother cell undergoes **meiotic-division** (reduction division) to form **tetrahedral tetrad** of spores and hence 4 spores (n).

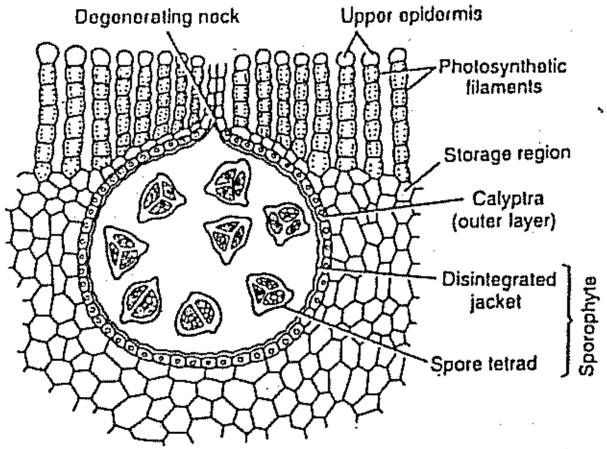


Fig. 12.10. V.T.S. of *Riccia* thallus showing mature sporophyte

- A few **spore mother cells**, although remain sterile and act as **nurse cells**, which are having vacuolated cytoplasm and disorganize to provide **nutrition** to developing spores.
- Fully developed sporophyte or sporogonium is simple structure, having **only capsule** or spore sac. There is no foot and seta.

○ Sporophyte or sporogonium of *Riccia* is **simplest** among bryophytes. The capsule is having a single layered wall, *i.e.*, **outer layer of calyptra** only (Inner layer of calyptra and sterile jacket formed by amphithecium also disorganize).

The liberation and dispersal of spores in *Riccia* is of very simple type. After death and decay of thallus, the spores are dispersed by air or by splashing rain.

Spores and germination of spores to form gametophytic thalli

Spore is the beginning of next gametophytic generation. Each spore is **pyramidal** or **tetrahedral** in shape, **uninucleate,** *i.e.*, with single haploid nucleus with **3 layered wall.** Outer wall layer is **exosporium** (thicker, cutinized and ornamented), middle thick **mesosporium** and inner thin **endosporium,** which is made of pectose and callose. The surface is having clear triradiate mark. In the mass of cytoplasm, stored food is present in the form of **oil-globules.**

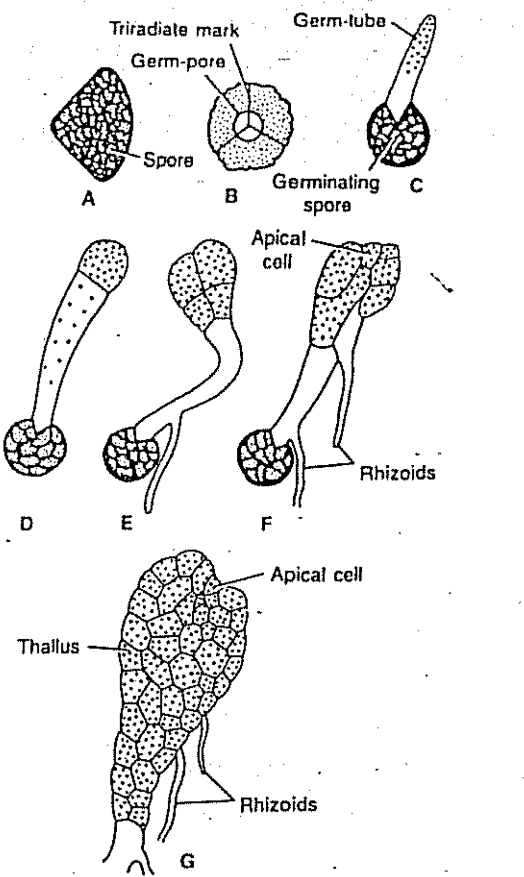


Fig. 12.11. A–G. Germination of spore and formation of gametophytic thallus

After liberation, the spores germinate in about 6–10 days in presence of light, low temperature and sufficient moisture contents. After absorbing water, the spore swells up. The exosporium and mesosporium rupture through triradiate mark and endosporium protrudes out in the form of germ tube, which is cut off by a transverse wall at tip. By further divisions (2 vertical and one transverse), an **apical cell** with two cutting faces is established at the apex. Activity of this apical cell results in formation of new **gametophytic thallus.**

Thus there are 2 generations in life cycle of *Riccia*. The main plant body is **gametophytic** (n). The gametophytic phase starts with formation of spores and ends with fertilization. The second phase is **sporophytic phase** ($2n$), which starts with zygote and ends with reduction division of spore mother cell. The sporophytic phase is **dependent** upon gametophyte. Thus there is **heteromorphic or heterologous alternation of generations** in *Riccia*. So life cycle in *Riccia* is **diplohaplontic.**

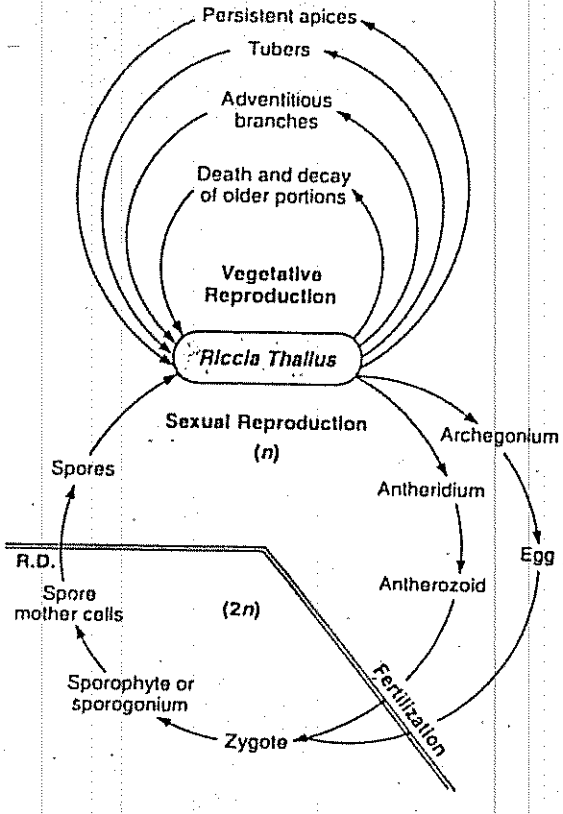

Persistent apices
Tubers
Adventitious branches
Death and decay of older portions
Vegetative Reproduction
Riccia Thallus
Sexual Reproduction (n)
Archegonium
Spores
Antheridium
R.D.
Egg
Spore mother cells
(2n)
Antherozoid
Fertilization
Sporophyte or sporogonium
Zygote

Fig. 12.12. Graphical representation of life cycle of *Riccia*

FUNARIA

Systematic position

Division — Bryophyta
Class — Bryopsida
Sub-class — Bryidae
Order — Funariales
Family — Funariaceae
Genus — *Funaria*

Funaria is known as **common moss** or **green moss** or **cord moss.** There are 117 species of *Funaria* which are worldwide or cosmopolitan in distribution. 25 species have been reported from India. Most common species are *Funaria hygrometrica, F. obtusa, F. attentua* and *F. fasicularis.*

Funaria grows well in recently burnt grounds rich in plant ashes (alkaline condition). Common places for its growth are moist rocks, moist walls and moist grounds.

Vegetative structure

The main plant body is gametophytic (n). There are two forms of it :

Alga like branched filamentous portion called **protonema** which is produced by germination of spores. It is ephemeral or short lived. Somewhat erect portion of protonema near the substratum, containing chlorophyll is **chloronema** whereas the deep portion, branched with oblique septa is the **rhizoidal portion.** It is non-green.

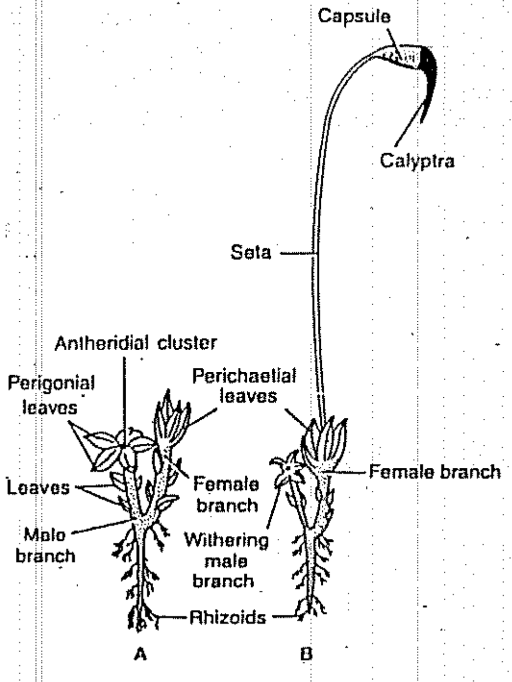

Capsule
Calyptra
Seta
Antheridial cluster
Perigonial leaves
Perichaetial leaves
Leaves
Female branch
Female branch
Male branch
Withering male branch
Rhizoids
A
B

Fig. 12.13. A, B. *Funaria* plant showing male and female branches

On protonema there are certain buds which give rise to **leafy erect gametophore,** made up of axis with spirally arranged leaves. It is 1–3 cm in height and is **monopodially branched.** The main branch of leafy gametophore bears male reproductive organs, *i.e.,* **antheridia** and the side branch is female branch. On lower portion the phyllotaxy is generally 3/8 while in upper portion it is 1/3, *i.e.,* crowded.

Leaves: These are small, sessile, ovate with acute apex and broad base. A distinct midrib is present.

Rhizoids: On the lower portion of the leafy gametophore, there are present branched, multicellular rhizoids with oblique septa. Initially the rhizoids are colourless and hyaline but at maturity they become dark in colour due to dark cell walls. If rhizoids are exposed to light they become green.

Anatomy

Stem (main axis): The outermost layer of axis is **epidermis** which is single layered, devoid of cuticle and stomata. Epidermal cells contain chloroplasts which are **assimilatory** in function. Epidermis is followed by **cortex** which consists of parenchymatous cells having chlorophyll in young stem but disappear at the maturity. Few outer layers of cortex become thick-walled. The central portion **medulla** is having small thick-walled cells performing the function of **conduction.**

Leaf: The leaf has many celled thick midrib region and is

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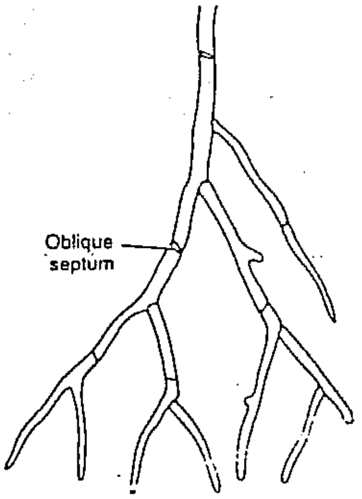


Fig. 12.14. Rhizoids of *Funaria*

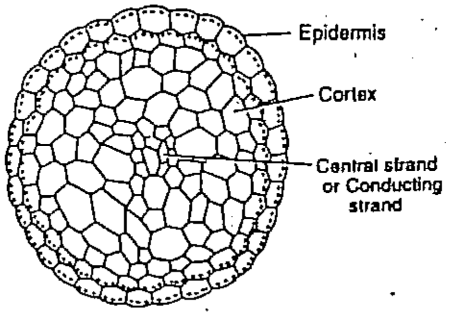


Fig. 12.15. T.S. axis of *Funaria* (young)

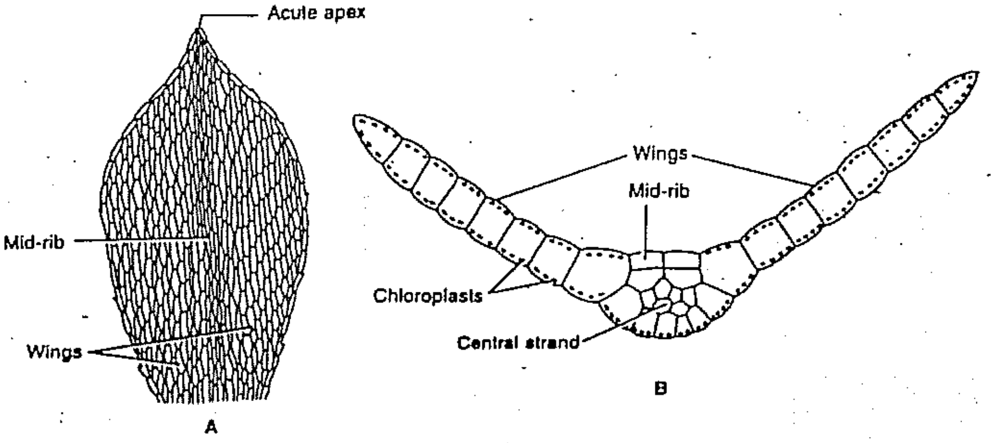


Fig. 12.16. A. A leaf B. T.S. of leaf of *Funaria*

single celled on margins or wings. Leaves are devoid of stomata and contain chlorophyll.

Reproduction

Funaria reproduces both by vegetative and sexual methods.

(A) Vegetative methods

Funaria reproduces vegetatively by several methods:

(i) **By protonema:** The haploid spores on germination give rise to alga-like filamentous branched portion called primary protonema. This protonema develops buds, from which leafy gametophyte arises. Sometimes this primary protonema breaks up into small fragments accidentally and these fragments give rise to leafy gametophores.

(ii) **Secondary protonema:** Sometimes other portions, *e.g.*, rhizoids, antheridia, etc., also give rise to protonema called secondary protonema, which develop buds and give rise to leafy gametophores.

(iii) **By gemmae and bulbils:** At the apices of the leaves multicellular bodies called **gemmae** are produced which on separation give rise to new plants. Similarly on rhizoids multicellular gemmae-like structures, **bulbils** are produced which give rise to gametophores.

(iv) **By apospory:** Any sporophytic tissue ($2n$) on injury give rise to a new moss plant which is diploid. This is called apospory.

(B) Sexual reproduction

The *Funaria* plants are monoecious and **autoecious**, *i.e.*, **male** (antheridia) and **female** (archegonia) reproductive organs are produced on the same plant but on different branches. Male organs mature first and hence *Funaria* plants are **protandrous.**

Antheridia: Main branch is male branch, which is called **antheridiophore.** The antheridia are present in group at the

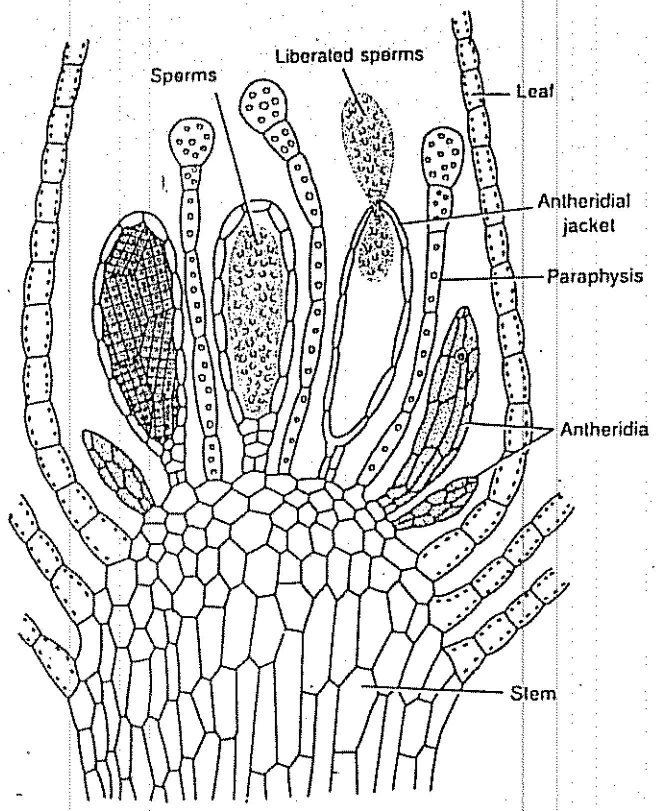


Fig. 12.17. L.S. antheridiophore or antheridial branch of *Funaria*

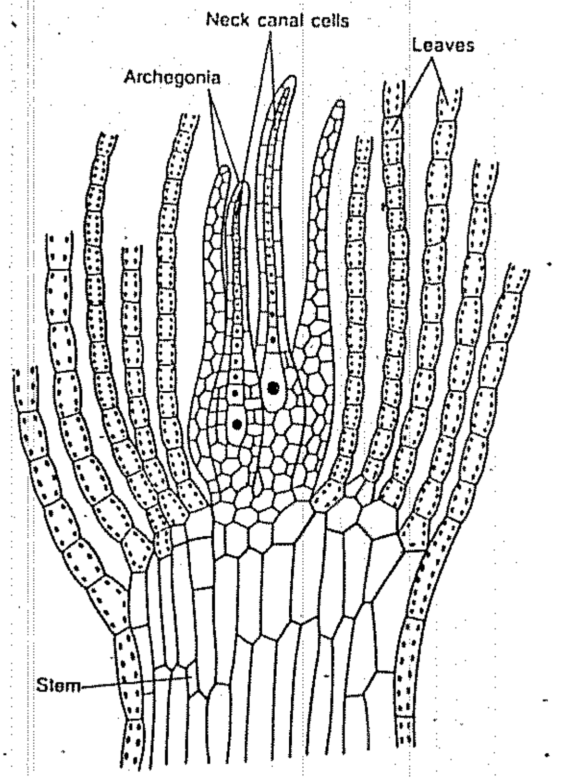


Fig. 12.18. L.S. archegoniophore or female branch of *Funaria*

apex of male branch. The antheridia intermix with sterile paraphysis. The group of antheridia along with paraphysis and perigonial leaves is collectively called **perigonium.**

Each antheridium is having short massive **stalk** and upper body which is surrounded by single layered sterile jacket. Inside the jacket there is mass of androcyte mother cells, each of which divides diagonally to produce two androcytes and each androcyte gives rise to a biflagellated coiled antherozoid or spermatozoid.

The antherozoids in *Funaria* are anteriorly biflagellated coiled structures. At maturity the antheridium mass absorbs water and swells upto form mucilaginous mass. Due to pressure the lid or opercular cells are blown away and the mass containing antherozoids comes out through the pore.

Archegonia: Archegonia are the female sex organs produced at the apex of female branch. They are intermixed with leaf-like paraphyses. The terminal cells of paraphyses in female branch is not globular. Besides many leaves called **perichaetial leaves** are present at periphery surrounding the group of archegonia forming a cup-like structure **perichaetium.**

Each archegonium is a flask shaped structure with basal, swollen portion called **venter** and upper elongated portion **neck.** Venter contains a basal large **egg cell** and upper smaller **venter canal cell.** Neck consists of **six or more neck canal** cells. At the tip of neck there are **four cover cells** or **lid cells.** The sterile jacket is two layered around venter while single layered around neck. At the base of venter, small massive stalk is present. At maturity the venter canal cell and neck canal cells degenerate to form mucilaginous mass along with **sugars.** It absorbs water and swells up and the lid cells are blown away. So the mucilaginous mass oozes out of the tip of the neck.

Fertilization

Antherozoids swim across the film of water, these are attracted by the sugars of the mucilaginous mass of degenerated neck canal cells. Out of many antherozoids, only one of them is able to fuse with the single egg to produce **zygote** ($2n$). The zygote without any resting period enlarges and divides to form **sporophyte or sporogonium.** The first division in zygote is transverse. The **epibasal** (upper) portion forms capsule and upper half of seta while **hypobasal** (lower) portion forms foot and lower half of seta.

Sporogenous tissue develops from **outer layer of endothecium.** The venter wall forms **calyptra** which is present initially around the sporophyte but later on it breaks.

Sporophyte

Fully developed **sporophyte** or sporogonium is made of three regions, *i.e.*, **basal foot, seta** and **capsule. Basal foot** is embedded in the apex of female branch and is conical in shape.

Its function is to absorb nutrients and to provide support for sporophyte.

Seta is a long thread-like intermediate portion of the sporophyte. The central portion of seta performs the function of conduction while the outer portion provides mechanical support and also helps in dispersal of spores by twisting movements. Capsule is the terminal pear shaped portion. Initially it is surrounded by calyptra but later on this calyptra breaks up. The capsule consists of three portions, *i.e.*, basal **apophysis, central theca and terminal operculum.**

Apophysis is basal portion of capsule in continuation with seta. The outer layer of apophysis is epidermis which has stomata for gaseous exchange. In capsule of *Funaria* stomata are present only in apophysis. Inner to epidermis there are chlorophyll containing cells which are assimilatory in function. These cells surround a central zone having vertically elongated cells lacking chloroplasts. Central zone performs the function of conducting strand.

In between apophysis and operculum the middle fertile part of capsule is theca. The outer layer of theca is epidermis, inner to which is 2–3 layered hypodermis. Central sterile portion of theca is called columella, outer to which is spore sac containing spores. The wall of spore sac is single layered on inner side and 2–3 layered on outer side.

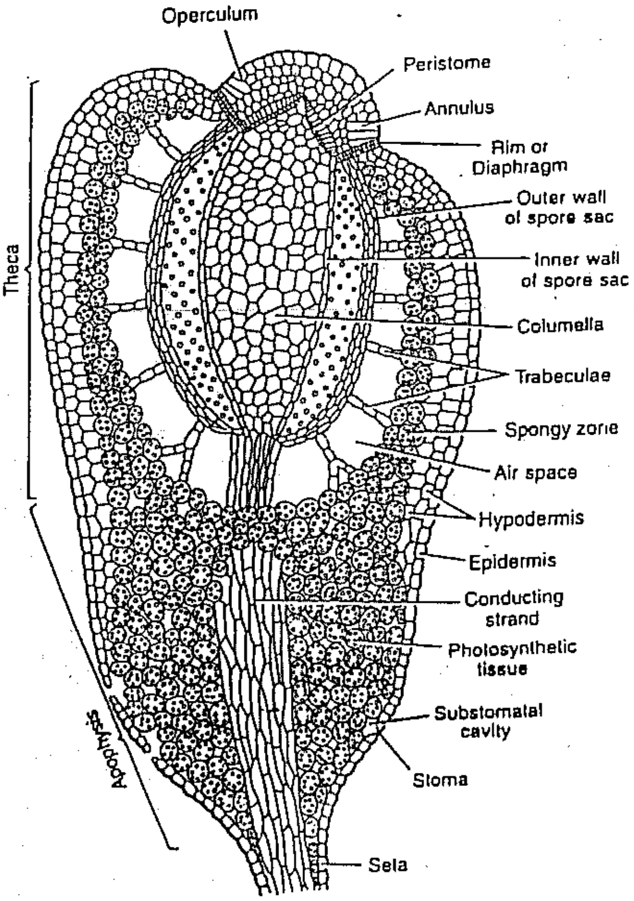

Operculum
Peristome
Annulus
Rim or Diaphragm
Outer wall of spore sac
Inner wall of spore sac
Columella
Trabeculae
Spongy zone
Air space
Hypodermis
Epidermis
Conducting strand
Photosynthetic tissue
Substomatal cavity
Stoma
Seta
Theca
Apophysis

Fig. 12.19. L.S. capsule of *Funaria*

Outer to spore sac there are present air spaces traversed by many portions of assimilatory cells called **trabeculae.**

The upper region of capsule is slightly oblique having upper cap-like portion called **operculum** which is separated through annulus (annulus has large thin-walled cells). After removal of operculum the peristomial teeth are exposed. There are 32 peristomial teeth in two rows, *i.e.*, 16 teeth in each row. Outer ring of these teeth called **exostome** is thick red affected by changes in moisture content, *i.e.*, hygroscopic in nature. Inner ring, *i.e.*, **endostome** is thin colourless, without thickening and non-hygroscopic in nature.

Dehiscence of capsule and dispersal of spores

The capsule swings in air due to twisting movements of long seta. It dries up. Inner thin-walled parenchymatous cells shrink and the cells of annulus break, operculum is blown away exposing the peristomial teeth. When there is moisture in the air, the outer ring of peristomial teeth absorbs water and swells up and fit over the inner peristomial teeth leaving no space for dispersal of spores. On approach of dry conditions, the outer ring of peristomial teeth looses water and dries up, because of which a space is formed and due to twisting movements of seta, the dispersal of spores occur.

- Spores have a long viability, *i.e.*, **8–15 years.**

Spores and their germination

Spores are small, rounded having 2-layered wall. Outer thick echinulate **exine,** and inner thin delicate **intine.** It is having

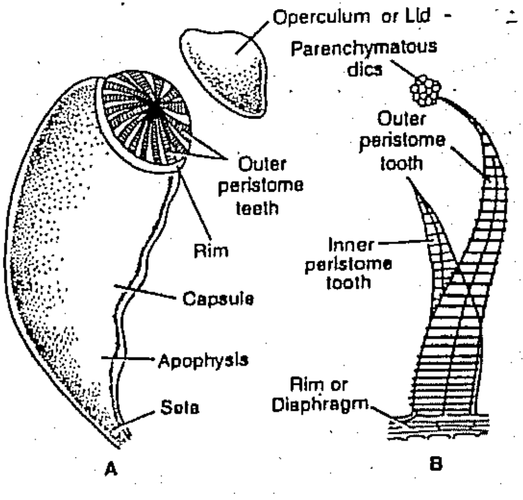

Operculum or Lid
Parenchymatous dics
Outer peristome tooth
Outer peristome teeth
Rim
Capsule
Apophysis
Seta
Inner peristome tooth
Rim or Diaphragm
A
B

Fig. 12.20. A. Capsule with operculum removed to show peristomial teeth B. Outer and inner peristomial teeth

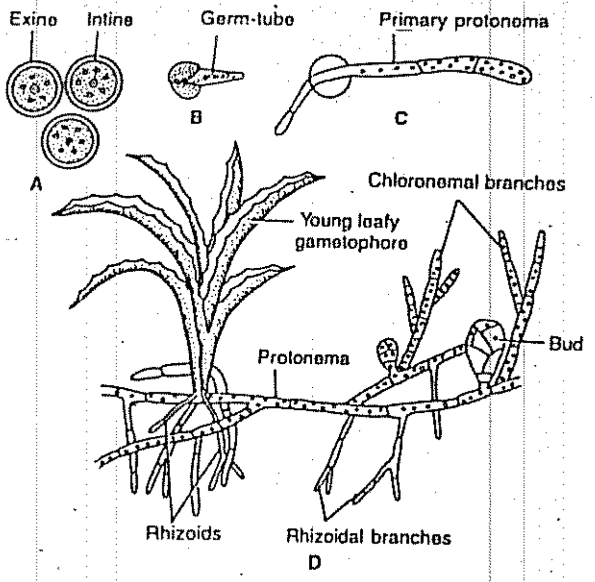

Exine
Intine
A
Germ-tube
B
Primary protonema
C
Chloronemal branches
Young leafy gametophore
Bud
Protonema
Rhizoids
Rhizoidal branches
D

Fig. 12.21. A–D. Spores and their germination in *Funaria*

single haploid nucleus, few oil drops and numerous chloroplasts.

On approach of favourable conditions the spore absorbs water, outer thick exine ruptures and intine comes out in the form of a germ tube which is cut off by means of a septum. Then it divides and enlarges to form a branched alga-like, filamentous, primary protonema.

Primary protonema is having two types of filaments or branches:

(i) Green thick, with straight septa and somewhat erect near the substratum, called **chloronemal branches** or **chloronema.**

(ii) Non green, thin with oblique septa called **rhizoidal branches** or **caulonema.** On the chloronemal branches, buds are produced near the septa which give rise to leafy erect gametophores. There are two generations in life cycle of *Funaria*, *i.e.*, **gametophytic generation** (n) which is independent and complex and **sporophytic generation** ($2n$) which is **partially dependent** upon gametophytic generation. These two generations follow each other in regular sequence. This is called **heteromorphic** or **heterologous** alternation of generations.

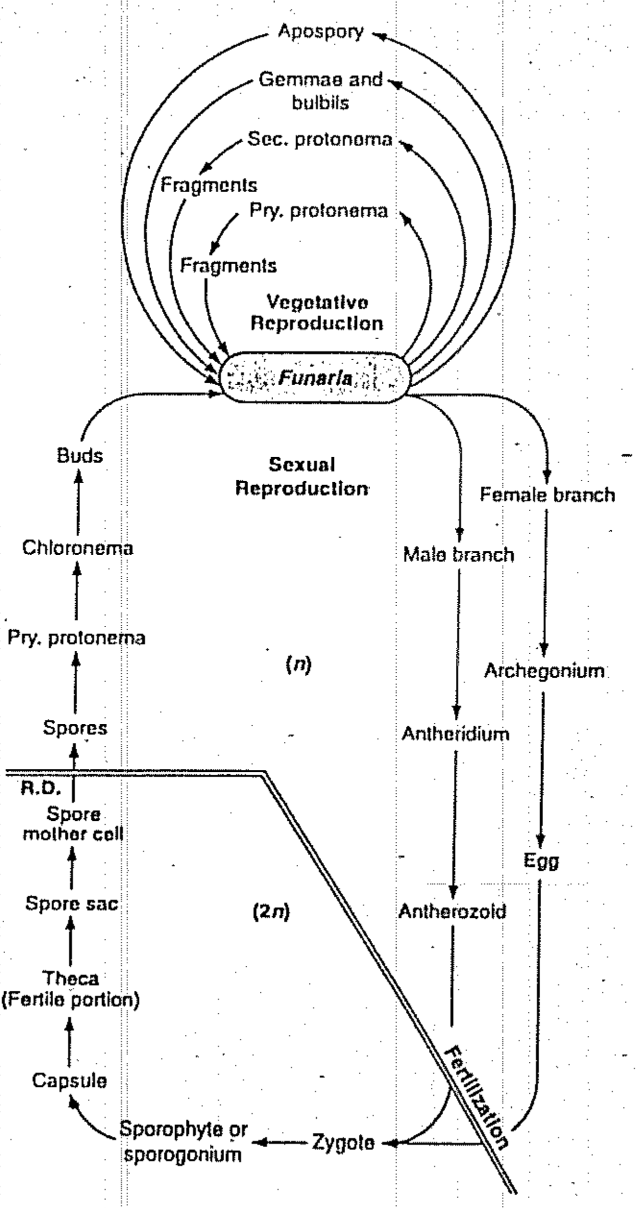

Apospory
Gemmae and bulbils
Sec. protonema
Fragments
Pry. protonema
Fragments
Vegetative Reproduction
Funaria
Buds
Sexual Reproduction
Female branch
Male branch
Chloronema
Pry. protonema
(n)
Archegonium
Spores
Antheridium
R.D.
Spore mother cell
Egg
Spore sac
(2n)
Antherozoid
Theca (Fertile portion)
Fertilization
Capsule
Sporophyte or sporogonium
Zygote

Fig. 12.22. Graphical representation of life cycle of *Funaria*

MULTIPLE CHOICE QUESTIONS

1. Most primitive land plants evolved are:
(a) Algae (b) Fungi
(c) Bryophyta (d) Pteridophyta

2. Which plant group is known as 'Amphibians of plant kingdom'? (MPPMT 2001)
(a) Pteridophyta (b) Bryophyta
(c) Algae (d) Fungi

3. The main plant body in bryophytes is:
(a) Sporophytic
(b) Gametophytic
(c) Gametophytic or sporophytic
(d) Neither gametophytic nor sporophytic

4. The term 'Atracheata' to bryophytes was given by:
(a) Kashyap (b) Campbell
(c) Smith (d) Tippo

5. Which is incorrect for bryophytes?
(a) Vascular tissue absent
(b) True roots absent
(c) Sex organs are jacketed
(d) Antherozoids are multiflagellated

6. Sex organs in bryophytes are:
(a) Unicellular and jacketed
(b) Unicellular and non-jacketed
(c) Multicellular and jacketed
(d) Multicellular and non-jacketed

7. A protective covering called 'Calyptra' is formed by:
(a) Wall of neck
(b) Wall of venter
(c) Stalk
(d) Formed as a new structure

*8. In bryophytes the zygote gives rise to sporophyte:
(a) After long resting period
(b) After short resting period
(c) No resting period
(d) No embryo and hence sporophyte formation

9. Sexual reproduction in bryophytes is:
(a) Isogamous (b) Anisogamous
(c) Oogamous (d) All of these

10. Sporophyte or sporogonium in bryophytes is:
(a) Fully independent
(b) Partially dependent
(c) Fully dependent
(d) Partially or fully dependent

11. Bryophytes are:
(a) Heterosporous
(b) Homosporous
(c) Homosporous or heterosporous
(d) None of the above

*12. Evolution of sporophyte in bryophytes is due to progressive .... of sporogenous tissue:
(a) Increase
(b) Sterilization
(c) Either increase or sterilization
(d) Remains constant

13. Bryophytes do not occur in:
(a) Mountains (b) Tropical forests
(c) Sea (d) Arctic region

14. The bryophyte, reported at maximum height (20,000 ft a.s.l.) is:
(a) *Buxbaumia* (b) *Dawsonia*
(c) *Aongstroemia* (d) *Fontinalis*

15. Which is an aquatic bryophyte?
(a) *Ricciocarpus natans* (b) *Riccia fluitans*
(c) *Fontinalis antipyretica* (d) All of these

16. Which bryophyte completes its life cycle fully under water?
(a) *Riccia fluitans* (b) *Riella*
(c) *Sphagnum* (d) None of these

17. Which is commonly known as 'Peat moss' or 'Bog moss'? [MDAT (Bihar) 1991; Pb. PMT 1997]
(a) *Polytrichum* (b) *Funaria*
(c) *Sphagnum* (d) *Riccia*

18. Epiphyllous bryophyte is:
(a) *Riccia* (b) *Marchantia*
(c) *Radula* (d) None of these

19. Saprophytic bryophyte is: (Pondicherry 1996)
(a) *Ricciocarpus* (b) *Buxbaumia*
(c) *Marchantia* (d) *Sphagnum*

20. Famous Indian bryologist was:
(a) P.N. Mehra (b) S.R. Kashyap
(c) K.C. Mehta (d) Mundkar

21. 'Liverworts of Western Himalayas' was written by:
(a) Kashyap (b) Campbell
(c) Smith (d) Ram Udar

22. The term 'bryophyta' was first of all given by:
(a) Linnaeus (b) Braun
(c) O. Tippo (d) Schimper

23. Bryophytes are divided in classes:
(a) 2 (b) 3
(c) 4 (d) 5

24. Liverworts are:
(a) Members of Bryophyta
(b) Members of Hepaticae class
(c) Members of Anthocerotae
(d) Members of Musci

25. Rhizoids in thalloid forms of bryophytes are present on:
(a) Dorsal surface (b) Ventral surface
(c) On margins (d) Everywhere

*26. Only capsule is present in sporophyte of:
(a) *Riccia* (b) *Marchantia*
(c) *Anthoceros* (d) *Funaria*

27. Elaters are present in capsule of: (AIIMS 2002)
(a) *Riccia* (b) *Marchantia*
(c) *Anthoceros* (d) *Funaria*

28. Which is commonly known as 'Hornwort'? (CPMT 2002)
(a) *Riccia* (b) *Marchantia*
(c) *Anthoceros* (d) *Sphagnum*

29. Presence of pyrenoid (algal character) is shown by which bryophyte? **(Raj. PMT 2001)**
(a) *Riccia* (b) *Marchantia*
(c) *Anthoceros* (d) All of these

30. Pseudoelaters are present in:
(a) *Marchantia* (b) *Riccia*
(c) *Anthoceros* (d) *Funaria*

31. Sporogenous tissue develops from amphithecium in:
(a) Hepaticopsida (b) Anthocerotopsida
(c) Bryopsida (d) All of these

32. The smallest bryophyte is:
(a) *Dawsonia* (b) *Fontinalis*
(c) *Zoopsis argentea* (d) *Funaria*

33. Tallest of mosses is:
(a) *Buxbaumia* (b) *Polytrichum*
(c) *Sphagnum* (d) *Dawsonia*

34. Name '*Riccia*' to a bryophyte was given in honour of a:
(a) Botanist (b) Lawyer
(c) Politician (d) None of these

35. 'Quacking bog' forming moss is:
(a) *Funaria* (b) *Polytrichum*
(c) *Dawsonia* (d) *Sphagnum*

36. Largest thalloid bryophyte is:
(a) *Marchantia* (b) *Plagiochasma*
(c) *Pellia* (d) *Monoclea*

37. Group of 20–100 fixed elaters (elatrophore) is present at base of capsule of:
(a) *Marchantia* (b) *Pellia*
(c) *Sphagnum* (d) None of these

38. Characteristic 'Gemma cups' are present in:
(a) *Riccia* (b) *Marchantia*
(c) *Pellia* (d) *Anthoceros*

39. A single 'gemma' in *Marchantia* gives rise to:
(a) Single thallus (b) 2 thalli
(c) 4 thalli (d) None of these

40. Bryophytes help in completion of:
(a) Hydrosere (b) Xerosere
(c) Both (a) and (b) (d) None of these

41. Which bryophyte is suitable for growth of oxylophytes?
(a) *Marchantia* (b) *Anthoceros*
(c) *Funaria* (d) *Sphagnum*

42. A bryophyte used as 'Antiseptic absorbent bandages' is:
(a) *Funaria* (b) *Polytrichum*
(c) *Sphagnum* (d) *Porella*

43. Which is commonly known as 'Cord moss' or 'Green Moss'?
(a) *Dawsonia* (b) *Tortula*
(c) *Funaria* (d) *Sphagnum*

44. Most common sps. of *Funaria* is:
(a) *F. fascicularis* (b) *F. obtusa*
(c) *F. hygrometrica* (d) *F. attentua*

45. *Funaria* grows well in:
(a) Soils rich in cow dung
(b) Soils rich in horse dung
(c) Recently burnt soils rich in plant ash
(d) None of the above

46. Alga-like, branched, filamentous body produced by germination of spore in *Funaria* is called:
(a) Primary protonema (b) Secondary protonema
(c) Chloronema (d) Caulonema

47. Which is incorrect about the leafy gametophore (main plant body) of *Funaria*?
(a) 1–3 cm in height
(b) Sympodially branched
(c) Having axis with spirally arranged leaves
(d) None of the above

48. The main branch of leafy gametophore in *Funaria* is:
(a) Female branch
(b) Male branch
(c) Either male or female branch
(d) No such differentiation

49. Leaves of *Funaria* are:
(a) Small, sessile, ovate with acute apex, without midrib
(b) Large, sessile, ovate with acute apex, with midrib
(c) Small, sessile, ovate with acute apex, with midrib
(d) None of the above

50. Rhizoids in *Funaria* are: **(CET J&K 2002)**
(a) Unicellular and smooth walled
(b) Unicellular branched
(c) Multicellular with oblique septa
(d) Multicellular branched with oblique septa

51. Leaves of moss plant contain:
(a) Stomata and chlorophyll
(b) Stomata but no chlorophyll
(c) No stomata, contain chlorophyll
(d) Devoid of stomata and chlorophyll

*52. In *Funaria*, the plants produced by 'apospory' are:
(a) Haploid (b) Diploid
(c) Both haploid and diploid (d) Triploid

53. Male and female sex organs in *Funaria* are present on:
(a) Different plants
(b) Same plant and on same branch
(c) Same plant but on different branches
(d) Not known

54. *Funaria* is:
(a) Homogamous (b) Protogynous
(c) Protandrous (d) None of these

55. In *Funaria*, the leaves surrounding the archegonial clusters are called:
(a) Perichaetial leaves (b) Perigonial leaves
(c) Paraphyses (d) Foliage leaves

56. Green, upright, sterile hair-like structures among antheridia in *Funaria* are known as:
(a) Apophysis (b) Paraphyses
(c) Perigonial leaves (d) Perichaetial leaves

57. The antherozoides or spermatozoides in *Funaria* are:
(a) Uniflagellated and 1 and 1/2 coiled
(b) Biflagellated and 2 and 1/2 coiled
(c) Biflagellated and 1 and 1/2 coiled
(d) Multiflagellated and straight

58. The neck of archegonium of *Funaria* has:
(a) 4 neck canal cells
(b) 2 neck canal cells

(c) 6 or more neck canal cells
(d) 1 neck canal cell

59. Simplest sporophyte among bryophytes is of:
(a) *Marchantia* (b) *Riccia*
(c) *Anthoceros* (d) *Funaria*

60. The sporogonium of *Funaria* has:
(a) Only capsule
(b) Only sporangium with spore
(c) Foot, seta and capsule
(d) Only foot and capsule

61. During development of sporophyte in *Funaria*, the first division in zygote is:
(a) Transverse
(b) Vertical
(c) Irregular
(d) Either transverse or vertical

62. Sporogenous tissue in *Funaria* develops from:
(a) Outer layer of amphithecium
(b) Inner layer of amphithecium
(c) Outer layer of endothecium
(d) Whole endothecium

63. The function of seta in moss is:
(a) Conduction (b) Mechanical
(c) Dispersal of spores (d) All of these

64. The apophysis region of moss capsule is:
(a) Assimilatory in function
(b) Has conduction and mechanical function
(c) Formation and dispersal of spores
(d) Retention of moisture

65. Stomata in moss capsule are present:
(a) Everywhere
(b) Only in theca region
(c) Only in apophysis region
(d) Not present

66. Which is the fertile portion of moss capsule?
(a) Seta (b) Theca
(c) Apophysis (d) Operculum
(CPMT 1997)

67. Mosses are indicator of:
(a) Air pollution (b) Water pollution
(c) Radiation pollution (d) Soil pollution

68. Which is hygroscopic in nature?
(a) Outer ring of peristome teeth
(b) Inner ring of peristome teeth
(c) Both (a) and (b)
(d) None of the above

69. Spore dispersal in *Funaria* is achieved by:
(a) Columella (b) Calyptra
(c) Peristome (d) Elaters

70. Viability of *Funaria* spores is:
(a) 8–15 days (b) 2 months
(c) Upto 15 years (d) Not known

71. The spore germination in *Funaria* gives rise to:
(MPPMT 1999)
(a) Leafy gametophyte (b) Primary protonema
(c) Secondary protonema (d) None of these

72. Leafy, erect gametophore is produced from buds on:
(a) Chloronema (b) Caulonema
(c) Both (a) and (b) (d) None of these

73. The sporophyte of moss is:
(a) Independent
(b) Fully dependent upon gametophyte
(c) Partially dependent upon gametophytic tissue
(d) None of the above

74. Bryophytes are of:
(a) Great economic value
(b) No value at all
(c) Great ecological importance
(d) A lot of aesthetic value

75. One character is common in between *Funaria* and *Dryopteris*, that character is: (BHU 1992)
(a) Monoecious gametophyte
(b) Dioecious gametophyte
(c) Heterosporous sporophyte
(d) Stele is protostele

76. 'Air gun mechanism' of spore dispersal occurs in:
(a) *Riccia* (b) *Marchantia*
(c) *Funaria* (d) *Sphagnum*

77. Which is responsible for spore dispersal in *Funaria*?
(a) Columella
(b) Peristomial teeth
(c) Twisting movement of seta
(d) Both (b) and (c)

78. Conducting tissue of moss is made of:
(a) Xylem and phloem (b) Parenchyma
(c) Collenchyma (d) Sclerenchyma

79. Unique feature of bryophytes compared to other plant groups is that:
(a) They produce spores
(b) Lack vascular tissue
(c) Lack roots
(d) Their sporophyte is attached to gametophyte

80. Protonema of moss is:
(a) Haploid (b) Diploid
(c) Sporophyte (d) Triploid

*81. The spore of *Funaria* contains:
(a) Single chloroplast
(b) Two chloroplasts
(c) Many chloroplasts
(d) No chloroplasts

82. Largest archegonium of plant kingdom is present in:
(CPMT 1993)
(a) *Riccia* (b) *Marchantia*
(c) *Funaria* (d) *Anthoceros*

83. Gametophytic generation is dominated in:
(a) Pteridophytes (b) Bryophytes
(c) Gymnosperms (d) Angiosperms

84. Apophysis in moss capsule is: (CBSE 1990)
(a) Upper part (b) Middle part
(c) Lower part (d) Fertile part

85. The function of ventral scales of *Riccia* is:
(a) Fixation
(b) Protection
(c) Absorption and protection
(d) Perennation and protection

86. In which of the following, an archegonium is present?
(a) *Funaria* (b) *Brassica*
(c) *Spirogyra* (d) *Rhizopus*

87. Which of the following shows alternation of generations? (BHU 1991)
(a) *Escherichia coli* (b) *Funaria*
(c) *Chlamydomonas* (d) *Spirogyra*

88. The peristome of moss capsule consists of: (CPMT 1997; AFMC 1998; EAMCET 2002)
(a) 8 teeth (b) 16 teeth
(c) 32 teeth (d) 64 teeth

89. The body of *Funaria* is:
(a) Differentiated into rhizoids, short axis and leaves
(b) Differentiated into root, axis and leaves
(c) Simple rosette thallus
(d) None of the above

90. To which group would you assign a plant which produces spores, embryo but lacks seed and vasculature? (CBSE 1992)
(a) Algae (b) Fungi
(c) Bryophyta (d) Pteridophyta

91. In *Marchantia*, the antherozoids are:
(a) Rod-shaped and biciliate
(b) Short, curved and biciliate
(c) Short, curved and multiciliate
(d) Long, curved and multiciliate

92. The thickness of *Funaria* leaf is:
(a) Single celled (b) Two celled
(c) Three celled (d) Four celled

93. The spores in the capsule of moss are formed in:
(a) Spore sac (b) Air cavities
(c) Annulus (d) Apophysis

94. Development of sporophyte directly from the gametophyte tissue is called:
(a) Apogamy (b) Apospory
(c) Syngamy (d) Parthenogenesis

95. Antherozoids (sperms) of *Funaria* are: (CPMT 1991; CBSE 1999)
(a) Biciliated spirally coiled (b) Biciliated with no coiling
(c) Quadriciliated (d) Aciliated

96. Jacket of *Riccia* gametangium is: (Raj. PMT 1992)
(a) Unicellular and one-layered
(b) Multicellular and one-layered
(c) Unicellular and multilayered
(d) Multicellular and multilayered

97. Which one of the following statements is not true of Bryophyta?
(a) They lack tracheids and sieve tubes
(b) They are photosynthetic
(c) Their zygote undergoes meiosis and then produces the sporophyte
(d) Their spores germinate producing gametophytes

98. Rhizoids of *Riccia* are: (CPMT 1991)
(a) Multicellular (b) Unicellular
(c) Branched (d) None of these

99. The gametophase of *Riccia* ends with:
(a) Gamete (b) Spore mother cell
(c) Spore (d) Oospore

100. The number of cells in neck canal of archegonia in moss is: (AFMC 1990)
(a) 1, binucleated (b) 2, uninucleated
(c) 4, uninucleated (d) 6–10, uninucleated

101. In which of the following protonema is seen? (CBSE 1990)
(a) *Rhizobium* (b) *Funaria*
(c) *Marchantia* (d) *Pinus*

102. In which of the following is a diploid included: (CBSE 1991; BHU 1997)
(a) Gametophyte and capsule of moss
(b) Gametophyte, archegonia and egg of moss
(c) Gametophyte, antheridia and sperm of moss
(d) Gametophyte and spores of moss

103. Why do mosses occur in regions which are moist?
(a) Because water is needed for fertilization
(b) Because rate of transpiration is very high
(c) Because it is a free floating hydrophyte
(d) None of the above

104. First land inhabiting plants are:
(a) Bryophytes (b) Angiosperms
(c) Gymnosperms (d) Pteridophytes

105. Moss capsule represents:
(a) Gametophyte (b) Sporophyte
(c) A part of protonema (d) A part of sorus

106. The air cavities in the capsule of moss are partitioned with delicate strands of cells. These are called:
(a) Partitions (b) Compartments
(c) Trabeculae (d) Septa

107. Largest gametophyte is found in: (CBSE 1991)
(a) *Funaria* (b) *Selaginella*
(c) *Pinus* (d) *Cycas*

108. Stomata are present in *Funaria* plant on:
(a) Foot (b) Capsule
(c) Seta (d) None of these

109. If a moss protonema is developed from few cells of capsule wall, then most probably it will be:
(a) Haploid (b) Diploid
(c) Triploid (d) Polyploid

110. Venter is the part of:
(a) Antheridium (b) Sporogonium
(c) Archegonium (d) Sporangium

111. Elaters are present in sporogonium of: (CBSE 1996)
(a) *Selaginella* (b) *Marchantia*
(c) *Riccia* (d) *Sphagnum*

112. Which is not a character of bryophytes?
(a) Presence of archegonia
(b) Independent sporophytes
(c) Motile sperms
(d) Water is essential for fertilization

113. Multicellular and jacketed sex organs are present in:
(a) *Funaria* (b) *Spirogyra*
(c) *Saccharomyces* (d) *Hibiscus*

114. Stomata having pores bounded by a single ring-shaped guard cell are found in:
(a) Capsule of *Funaria* (b) Leaf of fern
(c) Pinnule of *Cycas* (d) All of these

115. When moss spores germinate, they form: (CPMT 1990)
(a) Leafy gametophyte (b) Capsule
(c) Protonema (d) Rhizoids

116. The bryophyte of considerable economic importance is:
(a) *Marchantia* (b) *Funaria*
(c) *Riccia* (d) *Sphagnum*

117. Which of the following is least likely to occur along the sea coast?
(a) Brown algae (b) Mosses
(c) Green algae (d) Red algae

118. Protonema is a stage in the life cycle of: (CBSE 1993)
(a) All bryophytes (b) *Riccia*
(c) *Cycas* (d) *Funaria*

119. The gametophyte of moss is:
(a) Capsule (b) Seta
(c) Zygote (d) Protonema

120. In moss sporophyte, following is absent:
(a) Seta (b) Elaters
(c) Foot (d) Columella

121. Annulus of moss capsule separates:
(a) Theca and capsule
(b) Columella from apophysis
(c) Operculum and columella
(d) Operculum from theca

122. *Funaria* has: (MPPMT 1993)
(a) Unicellular, simple rhizoids
(b) Tuberculated rhizoids
(c) Distinct, branched coenocytic rhizoids
(d) Multicellular, oblique septate rhizoids

123. Gemmae are asexual reproductive bodies of:
(a) Gymnosperms (b) Mosses
(c) Liverworts (d) Algae

124. *Riccia* gametophyte is:
(a) Dioecious
(b) Monoecious
(c) Heterothallic
(d) Either monoecious or dioecious

125. *Funaria* is included in bryophytes because:
(a) It has heteromorphic alternation of generations
(b) Sporophyte is attached to gametophyte
(c) It lacks roots
(d) It lacks xylem

126. In moss, the sporophyte is differentiated into:
(a) Stem and leaves
(b) Roots, stem and leaves
(c) Rhizoids, stem and leaves
(d) None of the above

127. The female sex organ in *Riccia* and *Funaria* is:
(a) Antheridium (b) Archegonium
(c) Oospore (d) Paraphysis

128. A female gametangium of a bryophyte differs from that of a fungus in possessing:
(a) Large neck
(b) A venter
(c) Jacket layer with sterile cells
(d) A single egg cell

129. The main conducting part inside the capsule of *Funaria* is:
(a) Apophysis (b) Columella
(c) Spore sac (d) Seta

130. A moss differs from a fern in having:
(a) Swimming sperms
(b) A dependent sporophyte
(c) An independent gametophyte
(d) Alternation of generation

131. Plants of *Funaria* grow in tufts and are:
(a) Thallose
(b) Foliose
(c) Thallose and foliose
(d) Found in the hot springs of Rajgir

132. The archegonia of *Riccia* are:
(a) Embedded type and sessile
(b) Half embedded type and stalked
(c) Projecting type and stalked
(d) Projecting type and sessile

133. To which of the following groups of plants does the description given below fit? They have no roots, flowers and seeds, the plant body is characterised by a forked short, ribbon-like green thallus. The female reproductive organ is called archegonium:
(a) Pteridophytes (b) Basidiomycetes
(c) Bryophytes (d) Gymnosperms

134. Rhizoids of *Funaria* are:
(a) Multicellular
(b) Unicellular
(c) Multicellular, branched with oblique cross walls
(d) None of the above

135. The central or middle part of theca of capsule of *Funaria* is sterile and is known as: (CPMT 1992)
(a) Columella (b) Operculum
(c) Apophysis (d) Spore sac
(e) Protonema

136. Protonema is: (CPMT 1993)
(a) A fossil pteridophyte
(b) The juvenile phase of a moss gametophyte
(c) A part of the sporophyte of *Funaria*
(d) None of the above

137. The sporophytic phase in *Funaria* is well developed and is composed of:
(a) Foot and capsule (b) Foot, seta and capsule
(c) Capsule only (d) Spore sac

138. *Funaria* is fixed to the substratum by: (EAMCET 1992)
(a) Hairy roots (b) Adventitious roots
(c) Multicellular rhizoids (d) Unicellular rhizoids

139. S.R. Kashyap is famous for:
(a) Phycology (b) Mycology
(c) Bryology (d) Pteridology

140. In moss, medulla has:
(a) Piliferous layer (b) Endodermis
(c) Hadrome (d) Hypodermis

141. Moss plant with capsule is an example of: (CPMT 1991)
(a) Sporophyte completely dependent on gametophyte
(b) Sporophyte partially dependent on gametophyte
(c) Sometimes (a) and sometimes (b)
(d) None of the above

*142. What is the number of chromosomes in cells of theca of capsule of *Funaria*, if number of chromosomes in its rhizoids is 20?
(a) 10 (b) 20
(c) 40 (d) None of these

143. The dehiscence of moss capsule takes place by the rupture of the following: **(CPMT 1990)**
(a) Operculum (b) Peristome
(c) Annulus (d) Calyptra

144. In *Funaria*, stomata are present on the:
(a) Upper part of capsule (b) Lower part of capsule
(c) Leaf (d) Stem

145. Simplest sporophyte among bryophytes is of:
(a) *Marchantia* (b) *Riccia*
(c) *Anthoceros* (d) *Funaria*

146. Bryophytes flourish in moist and shady environments because:
(a) They cannot grow on land
(b) Their gametes fuse in water
(c) They lack vascular tissues
(d) They lack roots and stomata

147. Sporogenous tissue is of amphithecial origin in:
(a) *Marchantia* (b) *Anthoceros*
(c) *Funaria* (d) *Riccia*

148. Cells in leaves of *Funaria* are:
(a) Polyploid
(b) Diploid
(c) Haploid
(d) Sometimes haploid and sometimes diploid

149. The development of a sporophyte from moss gametophyte without gamete formation is called:
(a) Apospory (b) Apogamy
(c) Parthenogenesis (d) Amphimixis

150. *Funaria* is:
(a) Dioecious and paroicous
(b) Dioecious and synoicous
(c) Monoecious and autoicous
(d) Monoecious and paroicous

151. The centre of moss axis is occupied by:
(a) A large pith (b) Conducting tissue
(c) The xylem (d) Red coloured cells

152. Gametophytic generation is dominant in:
(a) Angiosperms (b) Pteridophytes
(c) Bryophytes (d) Gymnosperms

153. The antheridium of *Riccia* is a:
(a) Unicellular structure
(b) Multicellular structure
(c) Structure having 20 cells
(d) Structure having 60 cells

154. Which is commonly called 'Hair cap moss'?
(a) *Funaria* (b) *Sphagnum*
(c) *Pogonatum* (d) *Polytrichum*

155. Life cycle of *Funaria* is not completed without water: **(AMU 1994)**
(a) As the plant is delicate and will dry and die without water
(b) As branches will not develop
(c) As fertilization takes place in the presence of water only
(d) As *Funaria* is a hydrophytic plant

156. Which of the following is not common in *Funaria* and *Selaginella*? **(CBSE 1992)**
(a) Roots (b) Archegonium
(c) Embryo (d) Motile sperms

157. Spores of *Funaria* represent:
(a) Sexual propagules
(b) Gametes
(c) Beginning of gametophyte generation
(d) Beginning of sporophyte generation

158. In *Funaria*:
(a) Male and female reproductive organs are on the same plant and on the same branch
(b) Male and female reproductive organs are on different plants
(c) Male and female reproductive organs are on the same plant but on different branches
(d) None of the above

159. Bryophytes include:
(a) Liverworts and ferns (b) Mosses and ferns
(c) Mosses and liverworts (d) None of these

160. Sporogonium of *Riccia* is:
(a) Differentiated into seta and capsule
(b) Differentiated into foot, seta and capsule
(c) A simple capsule
(d) None of the above

161. In moss gametophyte, sterile uniseriate and many celled hair-like structures are called: **(AMU 1991)**
(a) Apophysis (b) Epiphysis
(c) Hypophysis (d) Paraphyses

162. In moss, spore on germination:
(a) Forms a protonema
(b) Forms a protonema on which moss plant comes out like a plant
(c) Produces antheridia and archegonia
(d) Directly forms a leafy gametophyte

163. Bryophytes are popularly called 'Amphibian plants' because:
(a) They grow on land
(b) They grow on damp soil and require water to carry out sexual reproduction
(c) They are aquatic
(d) All (a), (b) and (c)

164. How does the dehiscence of sporogonium and dispersal of spores occur in *Riccia*?
(a) By internal pressure of elaters
(b) By peristome teeth and seta
(c) By the death and decay of thallus and sporogonium and external pressure on calyptra
(d) By shrinking of annulus and explosion of capsule

165. Chloroplasts are present in the spores of:
(a) Yeast (b) *Dryopteris*
(c) *Funaria* (d) *Rhizopus*

166. A bryophyte differs from pteridophytes in: **(DPMT 1993)**
(a) Archegonia
(b) Lack of vascular tissue

(c) Swimming antherozoids
(d) Independent gametophytes

167. The spores of *Riccia* are:
(a) Smooth and rounded (b) Smooth and tetrahedral
(c) Spiny and rounded (d) Spiny and tetrahedral

*168. Two types of cells—hyaline and chlorophyllous green are characteristic of bryophytes in:
(a) *Sphagnum pappioglossum*
(b) *Funaria hygrometrica*
(c) *Porella heterophylla*
(d) *Polytrichum commune*

169. Dispersal of spores in *Funaria* is:
(a) By bursting of the capsule
(b) Through peristome
(c) Death and decay of sporogonium
(d) By bursting of the operculum

170. The two layers of teeth in the peristome of a moss are:
(a) Decorative parts functioning like sepals and petals in a flower
(b) Parts which help in the discharge of spores only when the capsule matures. After the operculum falls, they dry up and open out
(c) Parts which help in gradual dispersal of spores. The upper teeth are hygroscopic and open out only in dry weather; the lower ones check sudden dispersal
(d) Parts which help in the dispersal of spores. They are not hygroscopic and allow the discharge of spores by disintegration of capsule wall

171. In bryophytes, diploid chromosome number occurs in:
(a) Spore mother cells (b) Gamete nuclei
(c) Gametes (d) Spores

172. In *Riccia*:
(a) Sporophyte is parasitic over gametophyte
(b) Gametophyte is parasitic over sporophyte
(c) Sporophyte is a partial parasite
(d) Sporophyte is independent of gametophyte

173. What type of spores are in bryophytes?
(a) Triploid in nature (b) Tetraploid in nature
(c) Haploid in nature (d) Diploid in nature

174. *Marchantia* is a bryophyte because it lacks: (DPMT 1993)
(a) Independent sporophyte (b) Vascular tissues
(c) Roots (d) Seeds

175. Elaters of *Marchantia* exhibit: (CPMT 1991)
(a) Xerochasy (b) Hydrochasy
(c) Mutation (d) Circummutation

176. The rhizoids of *Riccia* are:
(a) Multicelled, smooth-walled and tuberculated
(b) Multicelled and tuberculated
(c) Unicelled, smooth-walled and tuberculated
(d) Unicelled and smooth-walled

177. Gametophyte is most developed in:
(a) Fern (b) Moss
(c) *Pinus* (d) *Cycas*

178. What is the characteristic branching pattern of *Riccia* thallus?
(a) Monopodial (b) Excurrent
(c) Dichotomous (d) Deliquescent

179. The peristome in *Funaria* consists of at maturity:
(a) One series of curved narrow triangular teeth, 16 in number
(b) One series of curved narrow triangular teeth, 32 in number
(c) Two series of curved triangular teeth, 8 teeth in each series
(d) Two series of curved, narrow triangular teeth, 16 teeth in each series

180. Spore mother cell in bryophytes is:
(a) Haploid (b) Diploid
(c) Triploid (d) Tetraploid

181. In which one of these the elaters are present along mature spores in the capsule (to help in spore dispersal)? (CBSE 1996)
(a) *Riccia* (b) *Funaria*
(c) *Marchantia* (d) *Sphagnum*

182. Stomata in *Funaria* are found in: (MPPMT 1996)
(a) Capsule (b) Foot
(c) Seta (d) No where

183. In the life cycle of *Funaria* sps., spore is/are the beginning of the generation/generations: (MPPMT 1997)
(a) Sporophytic
(b) Gametophytic
(c) Both gametophytic and sporophytic
(d) Peristome

184. In *Anthoceros* the central axis of tissue known as columella is formed from:
(a) Endothecium (b) Amphithecium
(c) Both (a) and (b) (d) None of these

185. Simple sporophyte is observed in:
(a) *Porella* (b) *Marchantia*
(c) *Riccia* (d) All of these

186. Which of the following plants is dioecious?
(a) *Porella* (b) *Riccia*
(c) *Marchantia* (d) All of these

187. The venter wall of the archegonium is double layered in:
(a) *Funaria* (b) *Riccia*
(c) *Anthoceros* (d) *Marchantia*

188. Sporogonium is a sporophyte consisting of:
(a) Capsule (b) Foot
(c) Seta (d) All of these

189. The archegonia of a lobe are covered by a two-lipped hanging membrane called:
(a) Involucre (b) Perichaetium
(c) Both (a) and (b) (d) None of these

190. In the gametophyte generation the function of root is taken up by unicellular or multicellular hair-like structures known as:
(a) Rhizome (b) Calyptra
(c) Rhizoids (d) All of these

191. The archegoniophore consists of stalk and star-shaped female receptacle in:
(a) *Riccia* (b) *Marchantia*
(c) *Funaria* (d) *Porella*

192. In bryophytes the embryo is not liberated but retained within the archegonium, whose basal portion enlarges to form a protective envelope known as:
(a) Theca (b) Root
(c) Calyptra (d) Paraphysis

193. Bryophytes can be differentiated from thallophytes on which of the following characters?
(a) In bryophytes sporophyte is completely dependent on the gametophyte
(b) Bryophytes are generally terrestrial
(c) Rhizoids are more common in bryophytes
(d) All of the above

194. Which of the following structures of *Funaria* is haploid in nature?
(a) Calyptra (b) Operculum
(c) Sporocytes (d) Peristomial teeth

195. Which of the following is diploid structure in bryophytes?
(a) Calyptra (b) Spores
(c) Operculum (d) None of these

196. The mosses which form dense extensive mats on the soil, prevent: **(CMC, Vellore 1991)**
(a) Soil erosion
(b) Falling of leaves
(c) Uprooting of trees
(d) Evaporation of water from the soil

197. How many spiral thickenings are present in an elater of *Marchantia*?
(a) 1 (b) 2
(c) 3 (d) 4

*198. The oldest fossil bryophyte recorded is a species of:
(a) *Muscites* (b) *Ricciopsis*
(c) *Marchantites* (d) *Hepaticites*

199. The bryophyte *Radula* may occur as:
(a) Psammophyte (b) Parasite
(c) Epiphyllous (d) Saprophyte

200. Which among the following was named after the Italian politician P.F. Ricci? **(EAMCET 1991)**
(a) *Funaria* (b) *Riccia*
(c) *Anthoceros* (d) *Dumortiera*

201. The earliest known fossil bryophyte belongs to:
(a) Cretaceous (b) Silurian
(c) Oligocene (d) Carboniferous

202. The reason why the bryophytes remain small whereas the pteridophytes can grow to great heights is because in pteridophytes:
(a) Spores get discharged by the hygroscopic annulus
(b) True xylem and phloem are developed
(c) Photosynthesis occurs vigorously
(d) Numerous rhizoids are found

203. The unique feature of bryophytes compared to other plant groups is that: **(Pb. PMT 1997)**
(a) They produce spores
(b) They lack vascular tissues
(c) They lack roots
(d) Their sporophyte is attached to the gametophyte

204. Bryophytes grow in moist and shady environments because: **(AMU 1992)**
(a) They cannot grow on land
(b) Their gametes fuse in water
(c) They lack vascular tissue
(d) They lack roots and stomata

205. Archegonia in *Marchantia* become inverted:
(a) Before fertilization
(b) After fertilization
(c) Before dispersal of spores
(d) Not inverted at all

206. Air pores present in upper epidermis of *Marchantia* are:
(a) Spherical (b) Oval
(c) Cylindrical (d) Barrel-shaped

207. The gametophytes of which of the following show gregareous habit?
(a) *Riccia* (b) *Marchantia*
(c) *Anthoceros* (d) *Funaria*

208. Which is true regarding spore sac of *Funaria*?
(a) Outer wall of spore sac is 3–4 layered, whereas inner wall is single layered
(b) Outer wall of spore sac is single layered, whereas inner wall is 3–4 layered
(c) Elaters are present
(d) Present outer to air space

209. Method of vegetative reproduction in *Funaria* is:
(a) Gemmae and bulbils
(b) Apospory
(c) Fragmentation of primary and secondary protonema
(d) All of the above

210. Which character is not shown by epidermis of axis of *Funaria*?
(a) Contains chloroplasts (b) Has stomata
(c) Devoid of cuticle (d) None of these

211. Unbranched photosynthetic filaments are characteristic of:
(a) *Riccia* (b) *Marchantia*
(c) Both (a) and (b) (d) None of these

212. Which bryophyte is of medicinal value?
(a) *Polytrichum* (b) *Marchantia polymorpha*
(c) *Sphagnum* (d) All of these

213. Which bryophyte is a source of fuel?
(a) *Polytrichum* (b) *Sphagnum*
(c) *Riccia* (d) None of these

*214. The greatest degree of sterilization in sporogenous tissue among bryophytes is found in:
(a) *Riccia* (b) *Marchantia*
(c) *Funaria* (d) *Anthoceros*

215. The shape of gametophyte in bryophytes is:
(a) Thalloid
(b) Leafy shoot
(c) Ranges from simple thallus to a leafy shoot
(d) None of the above

216. Most common method of vegetative reproduction in thalloid bryophytes is:
(a) By adventitious branches
(b) By gemmae
(c) By death and decay of older portions of thallus
(d) By protonema

217. Many buds develop on chloronemal branches of protonema of *Funaria* due to:
(a) Secretion of cytokinin
(b) Secretion of bryokinin hormone
(c) Secretion of auxins
(d) Secretion of gibberellins

218. The capsule of *Funaria* is:
(a) Pear-shaped with slight obliquity
(b) Pear-shaped, straight
(c) Mango-shaped, oblique
(d) Orange-shaped, oblique

219. Which one is a 'mixohydric moss'?
(a) *Funaria* (b) *Sphagnum*
(c) *Polytrichum* (d) None of these

220. Two flagella in antherozoids of bryophytes are of:
(a) Tinsel type (b) Whiplash type
(c) Pantonematic (d) May be of any type

221. In the life cycle of *Funaria* species spores are the beginning of generation: (MPPMT 1997)
(a) Sporophytic
(b) Gametophytic
(c) Both gametophytic and sporophytic
(d) Peristome

222. Spores are liberated from the sporophyte only by decay and decomposition of gametophyte in: (Pondicherry 1997; Manipal 1997)
(a) *Funaria* (b) *Anthoceros*
(c) *Riccia* (d) *Marchantia*

223. In *Funaria*, antheridia and archegonia develop on the same plant but on separate branches. Thus *Funaria* is:
(a) Dioecious but autoecious
(b) Dioecious by heteroecious
(c) Monoecious but autoecious
(d) Monoecious by heteroecious

224. Partially independent sporophyte is seen in: (Pondicherry 1997)
(a) *Pteris* (b) *Funaria*
(c) *Selaginella* (d) *Dryopteris*

225. Spores on germination in *Funaria* give rise to: (CPMT 1997)
(a) Protonema (b) Gametophyte
(c) Sporophyte (d) Capsule

226. What is the main feature of bryophytes?
(a) Gametophyte attached with sporophyte
(b) Sporophyte attached with gametophyte
(c) Ciliated sperms
(d) Capsule

227. Sporophyte is dependent on gametophyte in: (BHU 1995; CPMT 2002)
(a) Bryophytes (b) Gymnosperms
(c) Angiosperms (d) Pteridophytes

228. In which plant sex organs are embedded in the thallus?
(a) Moss (b) *Azolla*
(c) *Riccia* (d) Fern

229. In which one of the following the spore mother cells and elater mother cells belong to the same cell generation? (Pondicherry 1996)
(a) *Reboulia* (b) *Marchantia*
(c) *Dryopteris* (d) *Riccardia*

230. In *Funaria* male and female sex organs are produced on different branches of the same plant; male is on main axis and female is on lateral branch; such a moss is called: (AMU 1996)
(a) Acrocarpus moss (b) Pleuricarpus moss
(c) Apocarpous moss (d) Syncarpus moss

231. Among the following which one are non-vascular plants? (CET Chandigarh 1997; Manipal 1997)
(a) Pteridophytes (b) Bryophytes
(c) Angiosperms (d) Gymnosperms

232. In *Funaria* the haploid structure is: (AMU 1996)
(a) Protonema (b) Capsule
(c) Columella (d) Seta

233. Bryophytes are different from fungi in having: (AMU 1997)
(a) Land habit (b) Sterile jacket layers
(c) Multiflagellate gametes (d) Gametophytic plant body

234. In which of the following groups would you place a plant which produces spores and embryos but lacks seeds and vascular tissue (vasculature)? (CBSE 1992; BHU 1995)
(a) Fungi (b) Pteridophytes
(c) Bryophytes (d) Gymnosperms

235. The only positive evidence of aquatic ancestry of bryophytes is: (or, aquatic ancestry of bryophytes is evidenced by:) (BHU 1995, 97, 2002; PMET Punjab 2003)
(a) Their green colour
(b) Thread-like protonema
(c) Ciliated sperms
(d) Some forms are still aquatic

236. Which of the following has the largest gametophyte?
(a) *Funaria* (b) *Selaginella*
(c) *Pinus* (d) *Oryza*

237. An autoecious bryophyte is one in which: (AIIMS 1991)
(a) Male and female sex organs are produced on the same branch
(b) Male and female sex organs are produced on the same plant
(c) Male and female sex organs are produced on different plants
(d) Male and female sex organs are produced on different branches of the same plant

238. In *Funaria* which is haploid and gametophytic? (DPMT 1993)
(a) Operculum (b) Peristome
(c) Calyptra (d) None of these

239. Embryo is present in: (BHU 1993)
(a) Algae (b) Fungi
(c) Bacteria (d) Bryophytes

240. The female sex organs in bryophytes are called: (BHU 1994)
(a) Ascogonia (b) Archegonia
(c) Antheridia (d) Oogonia

241. Bryophytes can be separated from algae because they: (CPMT 1993; CBSE 1997)
(a) Are thalloid forms
(b) Have no conducting tissue

(c) Possess archegonia with outer layers of sterile jacket cells
(d) Contain chloroplasts in their cells

242. The amphibians of plant kingdom are: (CBSE 1996)
(a) Unicellular motile algae
(b) Multicellular non-motile algae
(c) Bryophytes with simple internal organization
(d) Pteridophytes with complex internal organization

243. In bryophytes: (CBSE 1994; BHU 1995)
(a) Sporophyte in itself completes the life cycle
(b) Gametophytes are dependent upon gametophyte
(c) Sporophytes are dependent upon gametophyte
(d) Sporophytic and gametophytic generations are independent

244. Spores are liberated from the sporogonium only by the decay of gametophyte in: (BHU 2001)
(a) *Funaria* (b) *Marchantia*
(c) *Anthoceros* (d) *Riccia*

245. The moss plant is: (CBSE 1995)
(a) Predominantly gametophyte with sporophyte attached to it
(b) Gametophyte
(c) Sporophyte
(d) Sometimes gametophyte and sometimes sporophyte

246. In moss: (CPMT 1998)
(a) Gametophyte is prominent
(b) Sporophyte is prominent
(c) Both are equally prominent
(d) None of the above

247. Bryophytes are dependent on water because: (CBSE 1998)
(a) Archegonium has to remain filled with water for fertilization
(b) Water is essential for fertilization for their homosporous nature
(c) Water is essential for their vegetative propagation
(d) The sperms can easily reach upto egg in the archegonium

248. Dichotomous branching is found in: (AFMC 1998)
(a) *Funaria* (b) Fern
(c) *Marchantia* (d) Liverworts

249. Spore of *Funaria*, on germination gives: (AFMC 1998)
(a) Protonema (b) Vegetative body
(c) Antheridia (d) Archegonia

250. In moss, rhizoids are found: (CPMT 1998)
(a) Dorsally (b) Ventrally
(c) Laterally (d) On upper side

251. Which is the correct statement for bryophytes? (CBSE 1999)
(a) Their sporophytic generation is smaller than gametophytic and is generally parasite
(b) Meiosis takes place in reproductive organs and results in the formation of gametes
(c) Their roots function for both conduction and support
(d) Their gametophytic generation is the dominant phase which produces spores and each spore gives rise to a new gametophytic plant

252. Peristome teeth in *Funaria* occur in how many whorls? (BHU 1991; CPMT 1999)
(a) One (b) Two
(c) Three (d) Four

*253. In *Funaria*, calyptra is derived from: (CPMT 2000; AFMC 2002; PMET Punjab 2003)
(a) Columella (b) Antheridium
(c) Capsule (d) Archegonium

254. In *Funaria* plant, stomata are present in: (MPPMT 2000; CPMT 2001)
(a) Foot (b) Seta
(c) Capsule (d) Leaf

255. Which of the following plants is amphibious in nature? (Manipal 2001)
(a) Mosses (b) Ferns
(c) Blue-green algae (d) Lichens

256. In Bryophytes, the female sex organ is called: (BHU 2000)
(a) Archegonium (b) Clostridium
(c) Ascogonium (d) Trichogyne

257. In moss plant, the archegonial clusters along with perichaetial leaves constitute: (BHU 2000)
(a) Foot and seta (b) Perichaetium
(c) Operculum (d) None of these

258. Sex organs in *Funaria* develop: (AIIMS 2000)
(a) In the protonema
(b) Inside the capsule
(c) In the axils of leaves
(d) At the tip of gametophore

259. Which of the following is absent in moss sporophyte? (MPPMT 2000)
(a) Seta (b) Foot
(c) Columella (d) Elater

260. *Funaria* gametophyte is: (AIIMS 2001; MPPMT 2001)
(a) Dioecious and autoecious
(b) Monoecious and heterothallic
(c) Monoecious and heteroecious
(d) Monoecious and autoecious

*261. Formation of sex cells was first seen in: [BCECE (P.T. Exam.) 2001]
(a) Pteridophytes (b) Bryophytes
(c) Gymnosperms (d) Angiosperms

262. Which of the following is true moss? [BCECE (P.T. Exam.) 2001]
(a) Irish moss (b) Bog moss
(c) Club moss (d) Reindeer moss

263. Peat moss is related to: (BCECE 2002)
(a) Club moss (b) Reindeer moss
(c) Irish moss (d) Bog moss

*264. Which of the following is the correct statement? (Raj. PMT 2001)
(a) No diploid structure is found in mature sporogonium of *Riccia*
(b) Sporogonium of *Riccia* is differentiated into foot, seta and capsule
(c) Sporogonium and spore mother cells of *Riccia* have chloroplast
(d) None of the above

265. A protective cap or hood like covering on the developing capsule in a moss or liverwort is known as: (BHU 2002)
(a) Spine (b) Calyptra
(c) Lodicule (d) Calyptrogen

266. The plant body of moss (*Funaria*) is: (AIIMS 2002)
(a) Completely sporophyte
(b) Completely gametophyte
(c) Predominantly sporophyte with gametophyte
(d) Predominantly gametophyte with sporophyte

267. *Funaria* and *Marchantia* differ from each other because *Funaria* possesses: (DPMT 2001)
(a) Ventral canal cell (b) Foot
(c) Calyptra (d) Protonema

268. Gametophyte is well developed in: (VVMC Safdarjung 2001)
(a) *Pinus* (b) Mango
(c) *Mentha* (d) Moss

269. The sporophyte of *Funaria* always begins development within the: (MPPMT 2002)
(a) Antheridium (b) Archegonium
(c) Capsule (d) Protonema

270. Which type of rhizoids are present in *Riccia*? (Raj. PMT 2002)
(a) Unicellular smooth
(b) Multicellular smooth
(c) Unicellular smooth and tuberculated
(d) Multicellular smooth and tuberculated

271. Which of the following statements is not true for bryophytes? (Orissa JEE 2002)
(a) They undergo meiosis to produce sporophyte
(b) They lack tracheids and sieve tubes
(c) They are photosynthetic
(d) Their spore germinates to produce gametophyte

272. This place in India is called 'The Golden Mine of Liverworts': (Kerala PMT 2003)
(a) Eastern Himalayas (b) Western Himalayas
(c) Western Ghats (d) Eastern Ghats
(e) Sunderbans

273. Protonema is the juvenile filamentous stage in the life cycle of: (Kerala PMT 2003; Jharkhand CECE 2003)
(a) *Funaria* (b) *Riccia*
(c) *Marchantia* (d) *Laminaria*
(e) *Cladophora*

274. Chlorenchyma is known to develop in: (CBSE 2003)
(a) Pollen tube of *Pinus*
(b) Cytoplasm of *Chlorella*
(c) Spore capsule of a moss
(d) Mycelium of a green mould

275. Plants forming spores but lacking seed and vascular tissue are: (AFMC 2003)
(a) Gymnosperms (b) Angiosperms
(c) Bryophytes (d) Pteridophytes

276. Calyptra is seen in: (Manipal 2003)
(a) Gametophyte (b) Sporophyte
(c) Archegoniophore (d) Antheridiophore

ANSWERS

1—c	2—b	3—b	4—d	5—d	6—c	7—b	8—c	9—c	10—d	11—b	12—b
13—c	14—c	15—d	16—b	17—c	18—c	19—b	20—b	21—a	22—b	23—b	24—b
25—b	26—a	27—b	28—c	29—c	30—c	31—b	32—c	33—d	34—c	35—d	36—d
37—b	38—b	39—b	40—b	41—d	42—c	43—c	44—c	45—c	46—a	47—b	48—b
49—c	50—d	51—c	52—b	53—c	54—c	55—a	56—b	57—c	58—c	59—b	60—c
61—a	62—c	63—d	64—a	65—c	66—b	67—d	68—a	69—c	70—c	71—b	72—a
73—c	74—c	75—a	76—d	77—d	78—b	79—d	80—a	81—c	82—c	83—b	84—c
85—c	86—a	87—b	88—c	89—a	90—c	91—a	92—a	93—a	94—a	95—a	96—b
97—c	98—b	99—a	100—d	101—b	102—a	103—a	104—a	105—b	106—c	107—a	108—b
109—b	110—c	111—b	112—b	113—a	114—a	115—c	116—d	117—b	118—d	119—d	120—b
121—d	122—d	123—c	124—d	125—b	126—d	127—b	128—c	129—b	130—c	131—b	132—b
133—c	134—c	135—a	136—b	137—b	138—c	139—c	140—c	141—b	142—c	143—c	144—b
145—b	146—b	147—b	148—c	149—b	150—c	151—b	152—c	153—b	154—d	155—c	156—a
157—c	158—c	159—c	160—c	161—d	162—b	163—b	164—c	165—c	166—b	167—b	168—a
169—b	170—c	171—a	172—a	173—c	174—a	175—b	176—c	177—b	178—c	179—d	180—b
181—c	182—b	183—b	184—a	185—c	186—c	187—a	188—d	189—c	190—c	191—b	192—c
193—a	194—a	195—c	196—a	197—b	198—d	199—c	200—b	201—d	202—b	203—d	204—b
205—b	206—d	207—d	208—a	209—d	210—b	211—a	212—d	213—b	214—c	215—c	216—c
217—b	218—a	219—a	220—b	221—b	222—c	223—c	224—b	225—a	226—d	227—a	228—c
229—b	230—b	231—b	232—a	233—b	234—c	235—c	236—a	237—d	238—c	239—d	240—b
241—c	242—c	243—c	244—d	245—a	246—a	247—d	248—d	249—a	250—c	251—a	252—b
253—d	254—c	255—a	256—a	257—b	258—d	259—d	260—d	261—b	262—b	263—d	264—a
265—b	266—d	267—d	268—d	269—b	270—c	271—a	272—b	273—a	274—c	275—c	276—b

EXPLANATION OF SELECTED QUESTIONS (*)

8. The zygote undergoes divisions without any resting period in bryophytes.

12. As we move from lower forms (*Riccia*) to higher forms (*Funaria*) in bryophytes, there is progressive sterilization of sporogenous tissue (spore forming fertile tissue) in sporophytes.

26. Simplest sporophyte in bryophytes is of *Riccia*, where only capsule is present.

52. When any injured tissue of sporophyte ($2n$) gives rise to moss plant, it is called apospory and thus moss plant so developed will be diploid.

81. The spore of *Funaria* is unique in having many chloroplasts.

142. As rhizoids are part of gametophytic (n) plant body, so n = 20 and as theca is part of capsule or sporophyte ($2n$), hence the number of chromosomes in theca will be $2n = 40$.

168. Two different types of cells are present in the leaf of *Sphagnum*—chlorophyllous or assimilatory cells and hyaline or capillary cells.

198. Oldest fossil bryophyte is *Hepaticites* (fossil hepaticae) from upper carboniferous period.

214. Maximum sterilization in sporogenous tissue is found in *Funaria*.

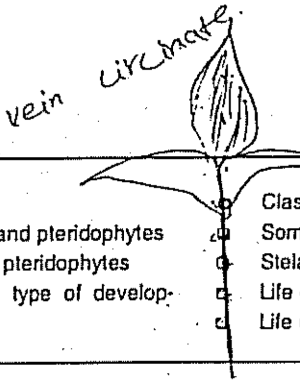
253. Calyptra is a protective covering developed from wall of venter of archegonium.

261. Bryophytes are the evolutionary first plants whose sex cells (gametes) are borne in special structures (antheridium and archegonium).

264. Mature sporogonium of *Riccia* is having only outer layer of calyptra as wall layer and spores (both haploid).

13

Pteridophyta



- General characters
- Resemblances between bryophytes and pteridophytes
- Differences between bryophytes and pteridophytes
- Eusporangiate and leptosporangiate type of development of sporangium in pteridophytes
- Classification of pteridophytes
- Some important points about pteridophytes
- Stelar system in pteridophytes
- Life cycle of *Selaginella*
- Life cycle of *Dryopteris* (Fern)

PTERIDOPHYTES

These are also known as **'Vascular Cryptogams'**. The term **'Cryptogams'** is made of 2 Greek words, *i.e.*, *Kryptos*, hidden + *gamos*, wedded, *i.e.*, these are the plants which reproduce by means of spores and do **not produce seeds.**

- Algae, fungi, bryophyta and pteridophyta are cryptogams, but out of them, first 3 (algae, fungi and bryophytes) are **lower cryptogams** and do not possess vascular tissue (xylem and phloem), whereas in pteridophytes, vascular tissue system is well developed and so these are **higher cryptogams or vascular cryptogams.**
- The term **'pteridophyte'** has been derived from a Greek word *Pteron,* **feather** and thus the name was originally given to this group because of their **pinnate** or feather **like fronds** (leaves).
- So pteridophytes or vascular cryptogams are a group of **seedless vascular plants**, that have successfully invaded the land and reproduce by means of spores.
- Peridophytes are the first vascular land plants (order Psilophytales, *e.g., Rhynia).*
- **Late palaeozoic** can be regarded as **'age of the pteridophyta'.**
- Pteridophytes are also called **'Snakes of plant kingdom'** or **'Botanical snakes'** as snakes, *i.e.*, reptiles (pteridophytes) evolved after amphibians (bryophytes).

The characteristic features of pteridophytes are as follows:

1. The dominant phase in the life cycle is **sporophyte** ($2n$), which is generally **herbaceous, rarely woody.**
2. The sporophytic plant is differentiated into root, stem and leaves.
3. The roots are mainly **adventitious** and the main root is short lived.
4. Stem is **herbaceous** or woody and it may have dorsiventral or radial symmetry.
5. Leaves may be small **(microphyllous)**, *e.g., Selaginella* or large **(megaphyllous)**, *e.g.*, ferns.
   - (Large leaves of ferns are called **fronds**).
6. In some cases like *Salvinia*, leaves are modified into adventitious roots.
7. Vascular system is well developed, *i.e.*, these are the plants in which xylem and phloem were first reported.
8. In xylem, **vessels are absent** and in phloem, **companion cells are absent**. *Selaginella* and *Equisetum* are exceptions where vessels are present.
9. Secondary growth is absent in pteridophytes, except *Isoetes*, where secondary growth occurs.
10. The sporophyte produces **meiospores** inside **sporangia** and all these spores may be of same type, *i.e.*, **homosporous** *(e.g., Lycopodium* and *Dryopteris)* or may be of two different types (*i.e.*, **heterosporous**) *(e.g., Selaginella, Stylites, Isoetes, Salvinia, Azolla, Pilularia, Regnelidium* and *Marsillea).*
11. The sporangia are subtended by leaf-like appendages called the **sporophylls**. The sporangia and sporophylls may be scattered throughout the vegetative axis or may be restricted to a **particular area.** In many cases, they are compacted to form distinct spore producing regions called **cories or strobili** *(e.g., Selaginella, Equisetum).* **The sporangia in some cases may be produced inside** specialized structures called **'sporocarps'** *(e.g., Marsillea, Salvinia, Azolla).*

V.V. Imp

12. The development of sporangium may be:

Eusporangiate ↓	or **Leptosporangiate type** ↓
Sporangium is developed from a group of cells *(e.g., Psilotum, Selaginella, Lycopodium, Equisetum).*	Sporangium is developed from a single-cell *(e.g., Salvinia, Azolla, Marsillea).*

13. The spores on germination give rise to flattened, dorsiventral, short-lived **prothallus (gametophyte)** which is **monoecious** in homosporous forms and **dioecious** in heterosporous forms.
   - Gametophyte is usually **independent** in pteridophytes.
14. The **gametophytes** are **exosporic** in homosporous forms and **endosporic** in heterosporous forms.
15. The gametophytes are greatly reduced in heterosporous vascular cryptogams.
16. The sex organs may be **projecting** or **embedded** type and they resemble the bryophytes in general plan of structure, *i.e.*, **multicellular** and **jacketed**.
17. The antheridia are having single layered jacket with a **short or no stalk.**
18. The archegonium is having **neck** and **venter** (venter not well developed). The neck is having 4 vertical rows of cells and each row is having 2–6 cells. The number of **neck canal cells** also varies from 1 in *Selaginella* to 14 in *Lycopodium*.
19. The **spermatozoids** or **antherozoids** may be **biflagellated** *(Selaginella)* or **multiflagellated** (ferns).
20. Water is necessary for the act of fertilization.
21. The zygote ($2n$) formed after fertilization is the initiation of sporophytic phase again and it undergoes divisions wholly (**holoblastic development**) or partially (**meroblastic development**) to form embryo.
22. The embryo may remain attached to sporophyte for a long time and it is the habit towards **seed habit** and **vivipary.**
23. There is **heterologous** or **heteromorphic** alternation of generations in pteridophytes like that of bryophyta.
   - Term **'Alternation of generations'** was first used by **Hofmeister (1851) in mosses and ferns.**

Resemblances between bryophytes and pteridophytes

1. They are adapted to terrestrial habitat with **few exceptions on both sides.**
2. Sex organs are of the same plan.
3. Water is necessary for fertilization.
4. Heteromorphic alternation of generations.
5. Absence of accessory asexual spores.
6. Seed development is absent in both.
7. Antherozoids or spermatozoids are **biflagellated** in **bryophytes and most of pteridophytes.**

Differences between bryophytes and pteridophytes

Three main differences are as follows:

1. The main plant body or dominant phase in life cycle of pteridophytes is sporophyte ($2n$), which is differentiated into **root, stem and leaves**, whereas in bryophytes it is gametophyte (n).
2. Vascular tissues (xylem and phloem) are present in pteridophytes and absent in bryophytes.
3. The gametophytic phase (**prothallus**) is **short-lived, reduced**, dependent on sporophyte in initial stages in pteridophytes. Rest of differences are minor.

Eusporangiate and leptosporangiate type of development of sporangium in pteridophytes

Eusporangiate development: Primitive type and is found in *Psilotum, Selaginella, Lycopodium, Equisetum*, etc. Here the **sporangium development** takes place by a **group of cells** and not a single cell. This type of sporangium is having **multilayered jacket** and contains a large number of spores (upto 2,000).

Leptosporangiate development: Complete development of sporangium takes place from a single cell or initial. Such sporangia have lesser number of jacket layers and contain lesser number of spores.

It occurs in *Salvinia, Azolla, Dryopteris* and *Marsillea*, etc.

CLASSIFICATION OF PTERIDOPHYTES

Smith divided the pteridophytes into following 4 divisions:

1. Psilophyta

Most primitive and **oldest known land inhabiting plants**, which are **rootless.** Main characters are:

(i) Only stem contains vascular tissue, *i.e.*, xylem and phloem.

(ii) For absorption of water and minerals, rhizoids are found in plants.

(iii) Leaves are usually lacking in plants.

(iv) **Homosporous** and spores are produced in terminal sporangia.

(v) Most of the plants are fossils, *e.g.*, *Rhynia, Horneophyton* and **only 2 living genera**, *i.e.*, *Psilotum* and *Tmesipteris*.

2. Lycophyta or Lepidophyta or Microphyllophyta

- These are commonly called **Club mosses** or **Spike mosses.**

(i) Plants are having root, stem and leaves.

(ii) All organs of the plant contain vascular tissue.

(iii) Members are **microphyllous**, *i.e.*, with small, thin leaves.

(iv) Most plants bear **cone** or **strobilus**, formed by overlapping sporophylls at apices of branches.

(v) Plants are homosporous, *e.g.*, *Lycopodium*, or heterosporous, *e.g.*, *Selaginella.*

3. Arthrophyta or Calamophyta or Sphenophyta

(i) Very small leaves are arranged in whorls at nodes.

(ii) There is deposition of silica in stems, so they are **rough** in touch.

(iii) Ridges and grooves are characteristic feature of stem of members of this group.

(iv) These are always **homosporous**, *i.e.*, producing only one type of spores, *e.g.*, Extinct genus *Sphenophyllum* and *Equisetum* (living member).

4. Filicophyta or Pterophyta

(i) Fan like leaves are characteristic features.

(ii) Plant body is well developed and stem is usually rhizome.

(iii) Stem is generally in the form of rhizome. In some ferns, stem is erect.

(iv) Sporangia are present in the middle or at margins of sporophylls on their lower surface.

(v) Spores on germination give rise to gametophytes (n), which produce **antheridia** and **archegonia**, *i.e.*, male and female sex organs.

(vi) They may be **homosporous**, *e.g.*, *Dryopteris, Pteris, Adiantum* or **heterosporous**, *e.g.*, *Marsillea.*

SOME IMPORTANT POINTS ABOUT PTERIDOPHYTES

1. Most primitive vascular land plants are Psilophytales members, *e.g.*, *Rhynia, Horneophyton (Hornea), Cooksonia, Asteroxylon* and *Psilophyton*, etc. Pteridophytes have a long fossil history. They formed the dominant flora of the **carboniferous period of palaeozoic era** when tree-like forms were common. Most part of coal is derived from these pteridophytes.
   - According to the fossil records, *Cooksonia* (of late silurian period of palaeozoic era, about 400 million years old) **is the oldest known vascular plant.**
   - *Psilophyton* is the first fossil member discovered by Sir William Dawson (1858).
2. *Rhynia* is a **fossil pteridophyte** (of lower devonian period of palaeozoic era), which is rootless and leafless and was discovered by **Kidson and Lang** (1913) from Rhynichert beds, Aberdeenshire, Scotland.
3. Telome theory was given by **Zimmermann** (1930), which explains elaboration of simplest sporophyte (like *Rhynia*) into modern, complex sporophyte.
4. Highest number of chromosomes in plants has been reported in a pteridophyte, *Ophioglossum*, where $2n = 1262$.
5. **Some common names of important pteridophytes:**

Member	Common name
(i) *Selaginella*	**Little club moss or spike moss**
(ii) *Lycopodium*	**Club moss**
(iii) *Isoetes*	**Quill wort**
(iv) *Equisetum*	**Horse tail**
(v) *Ophioglossum*	**Adder's tongue fern**
(vi) *Adiantum*	**Maiden hair fern** (because of shining, smooth and blackish hair-like petioles.)
(vii) *Adiantum caudatum*	**Walking fern** (because its leaf tips when come in contact with soil, form new plants as adventitious buds develop at leaf tips. This helps in the spread of fern over a large soil surface and thus derives the name 'walking fern').
(viii) *Dryopteris*	**Male shield fern or Beech fern or Hay scented fern.**
(ix) *Onychium*	**Golden fern**
(x) *Pteris*	**Sun fern**
(xi) *Pteridium*	**Bracken fern**
(xii) *Psilotum*	**Whisk fern**

6. **Aquatic ferns or pteridophytes:** *Salvinia, Azolla, Marsillea, Pilularia.*
7. **Free floating pteridophytes:** *Salvinia* and *Azolla.*
   - *Azolla* is the smallest pteridophyte. It contains blue-green algae (*Anabaena* and *Nostoc*) in its leaves and thus has N_2-fixing ability. It is used as a **biofertilizer.**
8. **Rootless fern or pteridophyte:** *Salvinia*—Roots are absent.
   - *Salvinia natans* grows luxuriantly in **Dal-lake** of Srinagar (Kashmir).
9. **Xerophytic pteridophytes or ferns:** *Woodsia elongata, Drynaria, Hypodermatium* and *Adiantum incisum.*
10. **Smallest fern:** *Anogramma leptophylla* (only 4–5 cm in height).
11. **Woody fern or tree fern:** *Cyathaea* (having upto 5–20 ft. woody stem). It is the largest pteridophyte.
12. Seed habit is shown by *Selaginella rupestris.*
13. *Selaginella bryopteris* is commonly known as **Sanjeevani.**
14. **Apogamy** is the development of sporophyte from gametophyte without fertilization (*i.e.*, from vegetative cells of gametophyte). Such sporophyte is **haploid.** Apogamy was first of all observed by **Farlow** (1874) in *Pteris cretica* and this term was coined by **De Bary** (1878).
15. A homoeopathic medicine **'Lycopodium'** is extracted from *Lycopodium* species.

STELAR SYSTEM IN PTERIDOPHYTES

Sachs (1875) reported that vascular tissues form a continuous column in the plants. This was further elaborated by **Van Tieghem and Douliot** (1886) and this was known as **stelar theory**, *i.e.*, vascular tissue system is fundamentally similar in roots and stems and in both, the cortex surrounds the central core of vascular tissue. **This central core of axis is known as stele.**

- The term stele has been derived from a Greek word which means **column or pillar.**

  Thus central core consisting of vascular tissue (xylem and phloem), pith (if present) and pericycle is stele.

  Stele = Xylem + Phloem + Pith (if present) + Pericycle.
- There is great controversy regarding the endodermis, whether it forms a part of stele or not, but generally the **central portion inside endodermis is called stele.**

Different types of steles found in pteridophytes

1. Protostele

This is the most **primitive type** of stele and all other types have been derived from it.

- Here, pith is **absent**. This primitive type of stele is found in *Lygodium, Lycopodium, Psilotum and Selaginella* sps., etc.
- Protostele is of different types:
  - (i) **Haplostele:** Here, solid round central core of xylem is surrounded by phloem and pericycle, *e.g., Selaginella kraussiana, Rhynia, Horneophyton, Cooksonia*, etc.
  - (ii) **Actinostele:** Here, central xylem is star shaped with radiating arms and phloem is present in separate patches, *e.g., Asteroxylon, Lycopodium serratum, Psilotum*, etc.
  - (iii) **Plectostele:** Here, xylem is present in form of separate plates and phloem is present between these xylem plates, *e.g., Lycopodium clavatum and L. volubile.*
  - (iv) **Mixed protostele:** Here, xylem is present in the form of discrete units embedded in phloem, *e.g., Lycopodium cernuum.*

2. Siphonostele

Here, pith is present in the centre of stele, *i.e.*, **protostele with pith is called siphonostele or medullated protostele is called siphonostele.**

- The origin of pith may be **intrastelar or extrastelar**, *i.e.*, cortex invasion into the stele.

It is further of two types:

(i) **Ectophloic siphonostele:** Here, phloem is present only on outer side of xylem, *e.g., Osmunda, Schizaea*, etc.

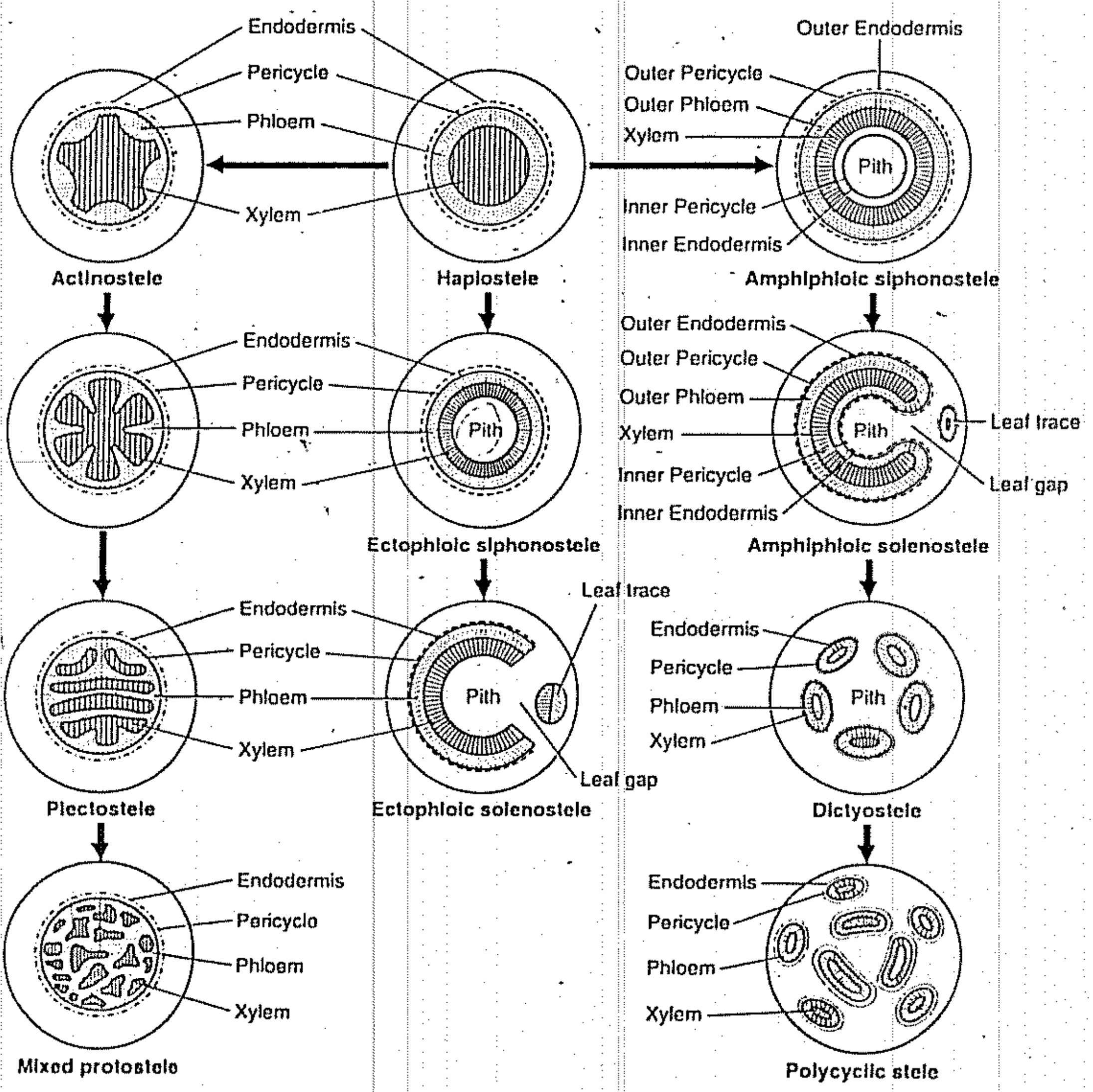

Endodermis
Pericycle
Phloem
Xylem
Actinostele
Haplostele
Outer Endodermis
Outer Pericycle
Outer Phloem
Xylem
Pith
Inner Pericycle
Inner Endodermis
Amphiphloic siphonostele
Endodermis
Pericycle
Phloem
Xylem
Pith
Ectophloic siphonostele
Outer Endodermis
Outer Pericycle
Outer Phloem
Xylem
Pith
Leaf trace
Leaf gap
Inner Pericycle
Inner Endodermis
Amphiphloic solenostele
Endodermis
Pericycle
Phloem
Xylem
Plectostele
Leaf trace
Pith
Leaf gap
Ectophloic solenostele
Endodermis
Pericycle
Phloem
Xylem
Pith
Dictyostele
Endodermis
Pericyclo
Phloem
Xylem
Mixed protostele
Endodermis
Pericycle
Phloem
Xylem
Polycyclic stele

Fig. 13.1. Different types of steles and their evolution in pteridophytes

(ii) **Amphiphloic siphonostele:** Here phloem is present on both sides of xylem, *e.g.*, *Marsillea*, *Adiantum*, *Dipteris*, *Platyzoma*, etc.

3. Solenostele

Here, the vascular cylinder is broken up by a single leaf gap or siphonostele with single leaf gap is called solenostele.

It may again be of ectophloic and amphiphloic siphonostele. It is found in some ferns.

4. Dictyostele

Here, there are a number of leaf gaps and the vascular cylinder breaks up into a number of smaller units called meristeles and each meristele is protostelic in nature.

It is characteristic of ferns, *e.g.*, *Dryopteris*, *Pteris*, etc.

5. Polycyclic stele

Here, more than one ring of vascular tissue is present. It is found in *Pteridium aquilinum*, where two concentric rings of vascular tissue are present; outer ring is having a number of meristeles (dictyostele) and inner ring is having only two meristeles. It is also found in *Pteris vittata* and *Marattia*.

- Protostele is most primitive type of stele and other types have been derived from it.
- Stele without leaf gap is called **cladosiphonic.**
- Stele with leaf gap is called **phyllosiphonic.**

SELAGINELLA

Systematic position

Division	Lycophyta
Class	Ligulopsida
Order	Selaginellales
Family	Selaginellaceae
Genus	*Selaginella*

Habitat

Selaginella is the single genus of its family Selaginellaceae. It is commonly called **"the little club moss"** or **"spike moss"** and is having about **760** species, out of which **70** species have been reported from India. *Selaginella* is mainly found in **damp shaded places.** A few species are **xerophytic** and can withstand the dry conditions for months together. In dry conditions, the plant rolls up into a compact ball and root system is disorganized. During the rainy conditions the ball on absorbing moisture, becomes green again. Such plants are called **"resurrection plants"** or **"bird's nest moss"**, *e.g.*, *S. lepidophylla* and *S. rupestris* (ornamental).

The epiphytic species grow on the branches and trunks of moss covered trees. The common epiphytic species are *S. chrysocaulos*, *S. kraussiana*, *S. oregana*, *S. chrysorrhizus.*

External morphology

The plant body is sporophytic (2*n*), which is an evergreen and delicate herb having adventitious roots. The plants show **great variation** in their morphology. Some species are **prostrate** growing upon the surface *(e.g., S. kraussiana)*, some are **suberect** *(e.g., S. trachyphylla)* and others are **climbers** *(e.g., S. allegans)*. Plants are many metres long in *S. willdenovii* and only few centimetre long in *S. spinulosa.*

Some species of *Selaginella* such as *S. kraussiana*, *S. helvetica*, *S. lepidophylla*, *S. chrysocaulos*, etc., have **dimorphic leaves**; these are grouped in subgenus *Heterophyllum.* Species having leaves uniform in size are grouped in the subgenus *Homoeophyllum.* These species are *S. spinulosa*, *S. rupestris*, *S. pygmaea* and *S. oregana*, etc.

Leaves are arranged spirally on the stem and are sessile, ovate or lanceolate with acute apex. Unbranched midrib is present in the centre of each leaf. In **dimorphic forms,** four spiral rows of leaves are present, 2 rows of smaller leaves on dorsal side and 2 rows of larger leaves on ventral side of the stem. The leaves are ligulate, *i.e.*, a flap-like outgrowth is present at the base on adaxial side called **ligule.** At the base of ligule, there is present a sheath of elongated cells called **glossopodium** (secretory).

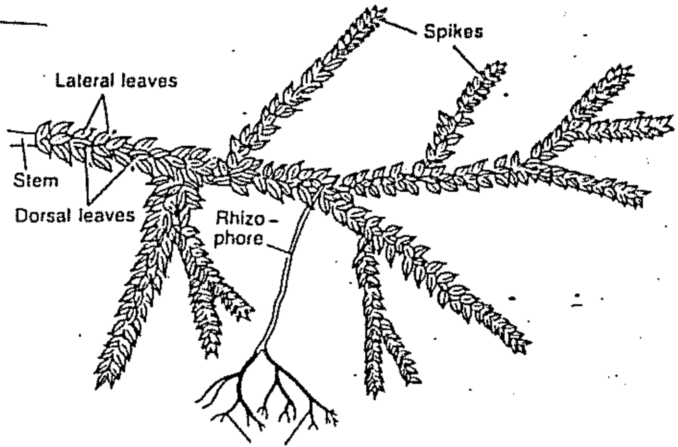


Fig. 13.2. Plant of *Selaginella* showing habit

Rhizophores: A leafless, colourless, **positively geotropic,** elongated cylindrical structure, growing downwards from point of bifurcation of stem, is called the **rhizophore.**

- Rhizophores are not present in *S. cuspidata.*

There is controversy regarding the **morphological nature** of rhizophore. There are three views:

1. First view: Some workers like **Van Tieghem** consider them as **capless roots,** because of the following characters:

(i) Positively geotropic.
(ii) Without nodes and internodes.
(iii) Without leaves and buds.
(iv) Anatomy of rhizophore is like that of roots (monostelic condition).
(v) Colourless.

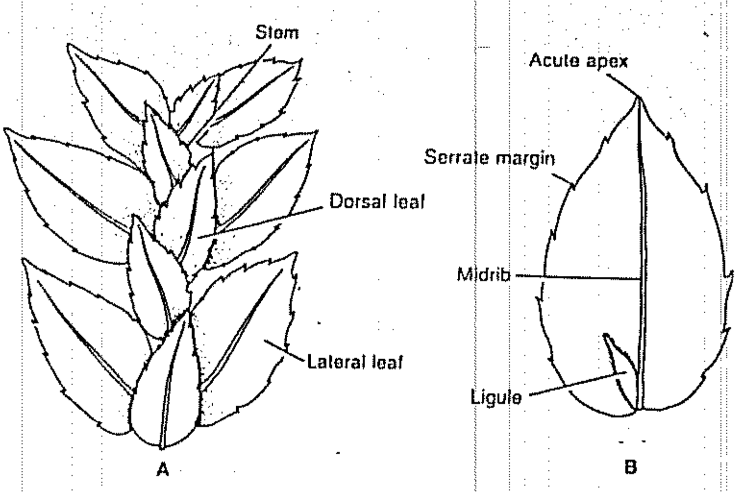

Stem
Dorsal leaf
Lateral leaf
A
Acute apex
Serrate margin
Midrib
Ligule
B

Fig. 13.3. *Selaginella*: A.Showing arrangement of leaves, B. A single leaf

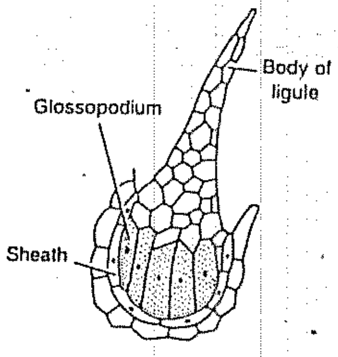

Body of ligule
Glossopodium
Sheath

Fig. 13.4. A ligule with basal glossopodium of *Selaginella*

2. Second view: According to Goebel, the rhizophores show the following characters of stem:

(i) Absence of root hairs and root cap.
(ii) Exogenous origin.
(iii) On touching the ground, produce adventitious roots.
(iv) Their position also justifies them to be stem.

3. Third view: Bower and other workers consider them neither root nor stem and they call rhizophores an **'organ sui generis'**, intermediate between root and stem.

Roots: The primary root in *Selaginella* is **short lived.** There are **adventitious roots** which arise at the tips of the rhizophores.

Anatomy

I. Stem

Main characters of stem are:

(1) **Monostelic** condition.
(2) The **protostele** is **diarch** and **exarch.**
(3) The endodermis except in xerophytic species (*S. lepidophylla* and *S. rupestris*) is interrupted by large intercellular spaces. This is called the **trabeculated endodermis.**

- More than one steles are present in the stem of some pteridophytes (*i.e.*, **polystelic** condition), *e.g.*, two steles are present in *S. kraussiana* and sixteen in *S. laevigata.*

II. Root

Root shows a **protostelic, monarch** structure. The protoxylem is **exarch.** The xylem is surrounded by phloem which is **horse shoe-shaped.**

III. Rhizophore

Its anatomy is similar to root. Again stele is **protostele** and there is **exarch** and **monarch** condition. As against root, it is having thick-walled epidermis.

IV. Leaf

There is chloroplast containing upper and lower epidermis (both single celled thick) and in between there is **mesophyll tissue.** Stomata are present only on lower epidermis (**hypostomatic**). Mesophyll tissue is not differentiated into palisade and spongy parenchyma, but it is made of green spongy cells with large intercellular spaces. The number of chloroplasts per mesophyll cell is **variable,** *i.e.*, **one in** *S. martensii*, **two in** *S. kraussiana* **and eight in** *S. willdenovii.*

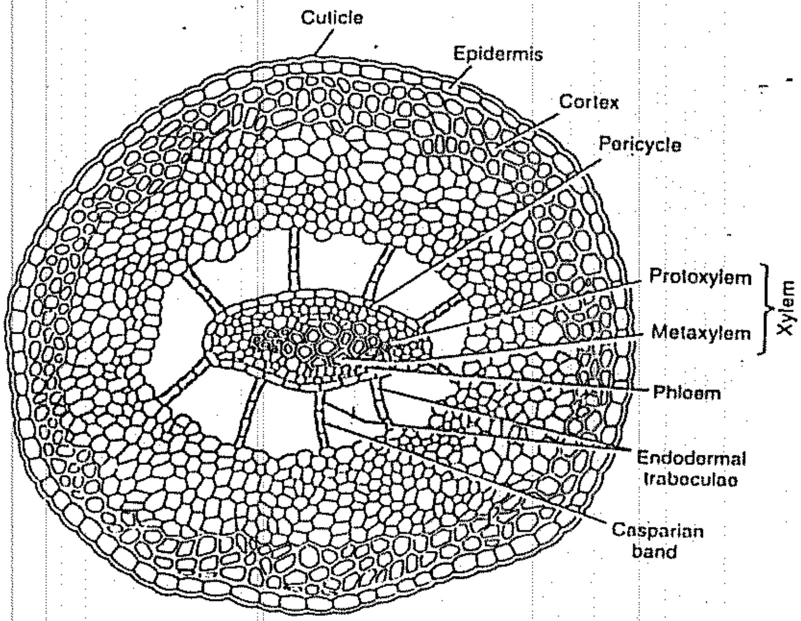

Cuticle
Epidermis
Cortex
Pericycle
Protoxylem
Metaxylem
Xylem
Phloem
Endodermal trabeculae
Casparian band

Fig. 13.5. T.S. stem of *Selaginella*

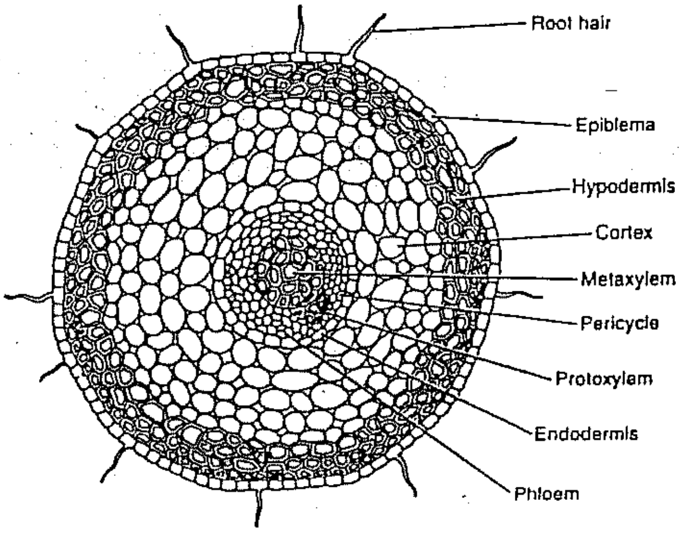

Root hair
Epiblema
Hypodermis
Cortex
Metaxylem
Pericycle
Protoxylem
Endodermis
Phloem

Fig. 13.6. T.S. root of *Selaginella*

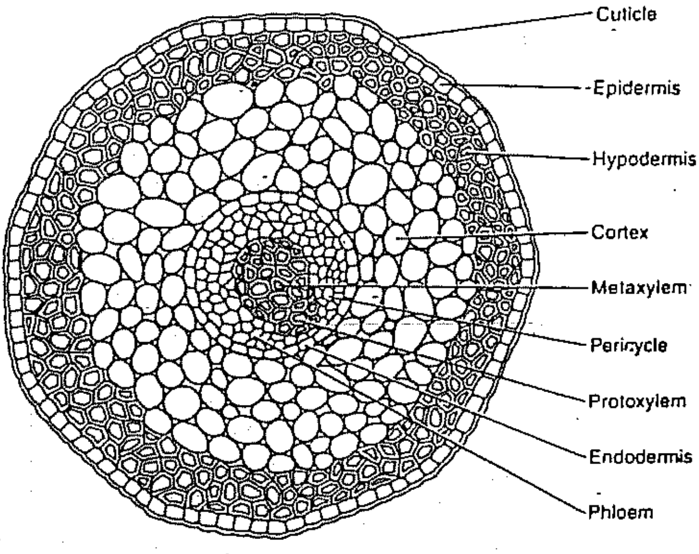

Cuticle
Epidermis
Hypodermis
Cortex
Metaxylem
Pericycle
Protoxylem
Endodermis
Phloem

Fig. 13.7. T.S. rhizophore of *Selaginella*

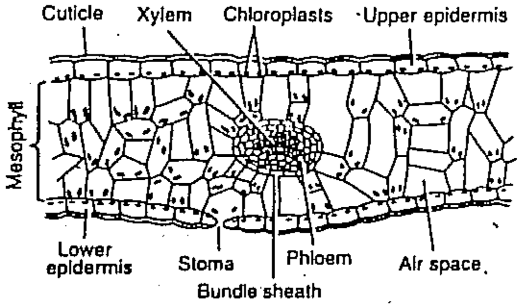

Cuticle
Xylem
Chloroplasts
Upper epidermis
Mesophyll
Lower epidermis
Stoma
Phloem
Air space
Bundle sheath

Fig. 13.8. V.S. of leaf of *Selaginella*

- Further many pyrenoids are present in each chloroplast (like *Anthoceros* of bryophyta).

In the centre, there is single, concentric, amphicribal vascular bundle, where there is no differentiation of xylem into protoxylem and metaxylem.

Reproduction

By two methods:

1. Vegetative reproduction

It is rare in *Selaginella*. Still, the main methods are:

(a) **Fragmentation:** It occurs during very humid conditions. Some branches act as **adventitious branches**, which get separated from the plant and give rise to new *Selaginella* plants, *e.g.*, in *S. rupestris*.

(b) **By resting buds:** In some cases, terminal leaves get overlapped and become fleshy and form **resting buds**, which are means of vegetative reproduction, *e.g.*, in *S. chrysocaulos*.

(c) **By tubers:** In *S. chrysorrhizus*, some branches penetrate into substratum and at terminal ends swell to form tubers, which give rise to new plants.

(d) **By apogamy:** In some cases, development of sporophyte occurs directly from gametophyte without intervention of sex organs; it is called **apogamy** and such plants are genetically **haploid**.

2. Sexual reproduction

The reproductive structure in *Selaginella* is **strobilus** or **spike**. It is a sessile structure and develops at the terminal ends of the branches and its length varies from 1/4th of an inch to 2–3 inches in different species.

A **strobilus** is having many ligulate sporophylls arranged in cluster, each bearing a small, short, stalked **sporangium** on its upper surface. The sporangia are of two types:

(i) **Megasporangia:** Borne on megasporophylls and contain four large spores.

(ii) **Microsporangia:** Borne on microsporophylls having a large number of small spores. Thus *Selaginella* is **heterosporous**.

- In some cases **strobilus** contains either micro or megasporophyll, *i.e.*, in *S. gracilis* and *S. atroviridis*, while *S. martensii* and *S. caulescens* show intermixed micro and megasporophylls. Some sps. possess megasporangia on the ventral side and microsporangia on the dorsal side, *e.g.*, *S. oregana* and *S. inaequalifolia*.

In most of the cases, the **strobilus** or **spike** bears two types of sporophylls; the lower are **megasporophylls** and the upper ones are **microsporophylls**. In

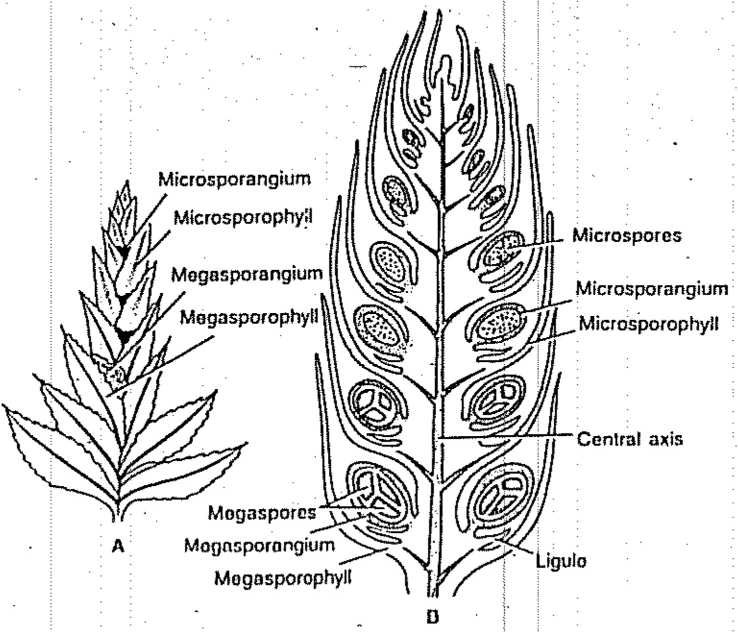


Fig. 13.9. *Selaginella:* A. A strobilus showing compactly arranged sporophylls B. L.S. through strobilus

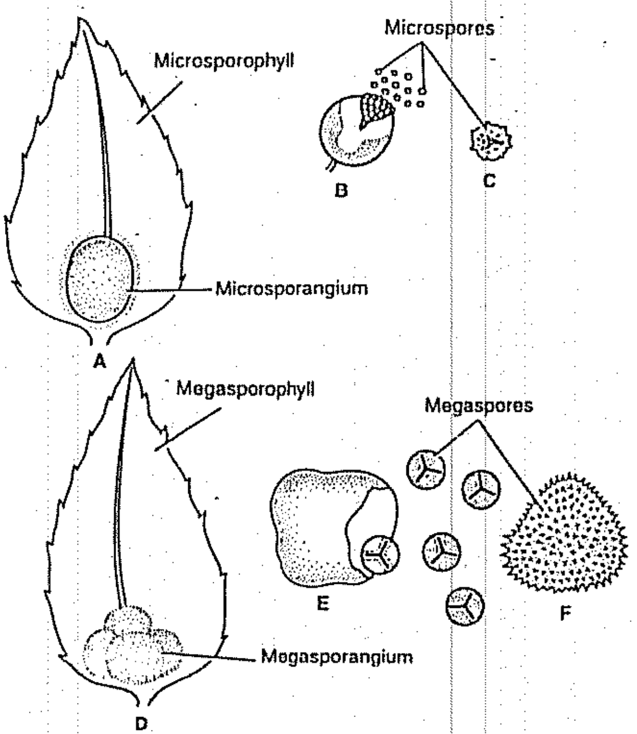


Fig. 13.10. *Selaginella:* A. A microsporophyll with microsporangium B. A dehisced microsporangium C. Microspore D. A megasporophyll with megasporangium E. A dehisced megasporangium F. Megaspore

S. kraussiana there is single **megasporophyll** at the base of spike and the rest of upper are **microsporophylls.**

Microsporangium: It is pale yellow, oval or spherical body having a short stalk. The main body consists of a wall having two layers, inside which are present **numerous small microspores** (400–2000).

Megasporangium: It is pale greenish and contains chalky white, yellow or orange **megaspores.** The megasporangium is **four-lobed** having **four large megaspores.** In *S. rupestris,* there is only a **single megaspore.**

- Development of sporangium is of **eusporangiate** type.

Dehiscence of sporangium

The spores start germinating inside the sporangium before their release; this is known as **precocious germination.** On maturation, the sporangium splits vertically from the upper end into two valves (vertical apical splitting). The lower cup-shaped portion shrinks and the spores come out through apical slits. This is brought about by cohesion owing to **hygroscopic changes** in the apical and lateral part of the sporangial wall. The liberation of spores takes place at intervals in small masses.

Germination of microspore

The microspores are small (0.015 mm–0.06 mm in diameter) having rounded base covered by 2-layered wall, outer thick **spiny exine** and inner thin **smooth intine.**

The first division leads to formation of a small **prothallial cell and a large antheridial cell.** The larger antheridial cell, by further divisions, gives rise to central group of **four primary androgonial cells,** surrounded by **eight jacket cells. At this 13-celled stage** (1 prothallial + 8 jacket cells and 4 primary androgonial cells), the microspore is shed from **microsporangium.** Each of the central groups of cells divides and redivides and finally forms **about 256 spirally coiled antherozoids** with two flagella (biflagellated); the jacket cells disintegrate. It takes about three weeks for germination of microspore and formation of antherozoids or sperms.

Germination of megaspore

Generally the megaspore germinates inside the megasporangium (*i.e., in situ*). In some sps., megaspores are shed after the development of first archegonium, *i.e.,* in *S. kraussiana,* while in *S. apoda* and *S. rupestris,* megaspores are not liberated till a well developed embryo is formed.

During the development of **female gametophyte,** the protoplasm after contraction forms a small sac-like structure. The outer wall bursts into two layers, the exospore and mesospore. At this stage, megaspore contains a haploid nucleus which by division produces many nuclei. Wall formation takes place in the upper beak-like portion and a small-celled cellular tissue is formed. This is one celled thick at the sides and three celled thick in the middle. This is female prothallus. Some superficial cells at apex enlarge and act as **archegonial initials** and form the **archegonia**. The megaspore bursts exposing the female prothallus. Vestigial rhizoids develop.

Archegonium consists of very short neck having a single neck canal cell and a venter, having a single ventral canal cell and an egg.

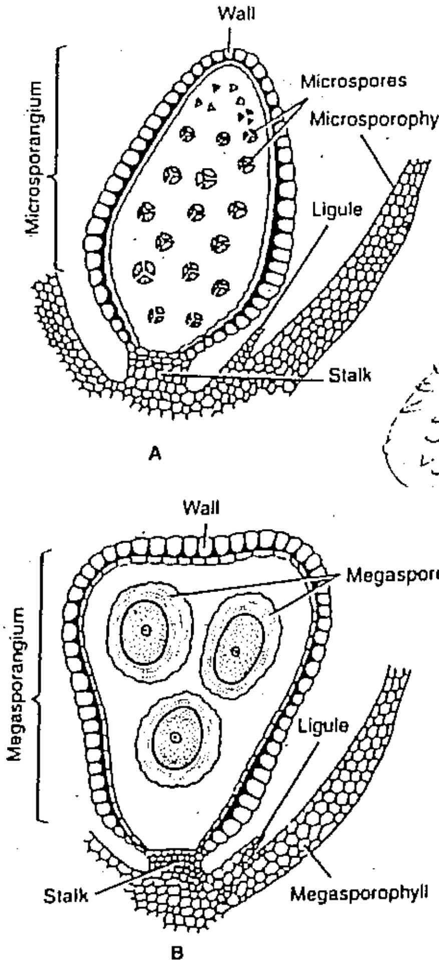

Wall
Microsporangium
Microspores
Microsporophyll
Ligule
Stalk
A
Wall
Megaspores
Megasporangium
Ligule
Stalk
Megasporophyll
B

Fig. 13.11. *Selaginella:* A. V.S. microsporangium B. V.S. megasporangium

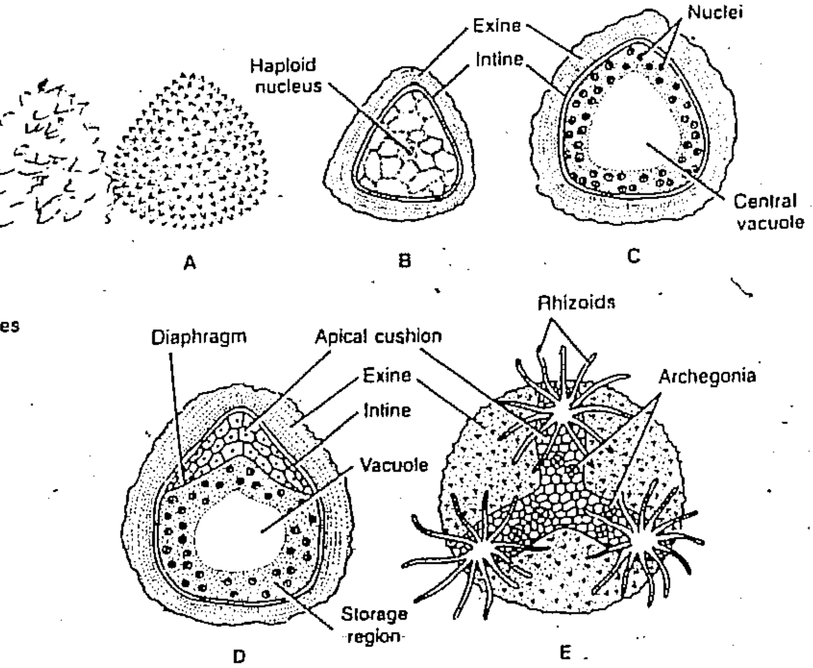

A
Haploid nucleus
Exine
Intine
B
Nuclei
Central vacuole
C
Diaphragm
Apical cushion
Exine
Intine
Vacuole
Storage region
D
Rhizoids
Archegonia
E

Fig. 13.13. Germination of megaspore into female gametophyte in *Selaginella*

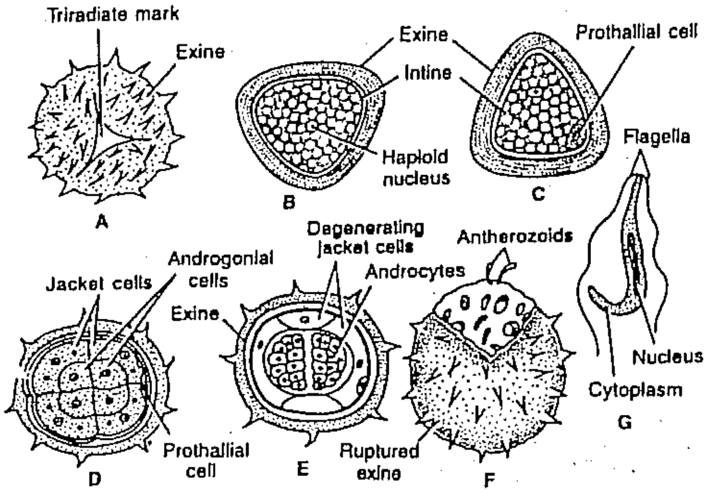

Triradiate mark
Exine
A
Exine
Intine
Haploid nucleus
B
Prothallial cell
C
Flagella
Nucleus
Cytoplasm
G
Jacket cells
Androgonial cells
Exine
Prothallial cell
D
Degenerating jacket cells
Androcytes
E
Antherozoids
Ruptured exine
F

Fig. 13.12. Germination of microspore into male gametophyte in *Selaginella*

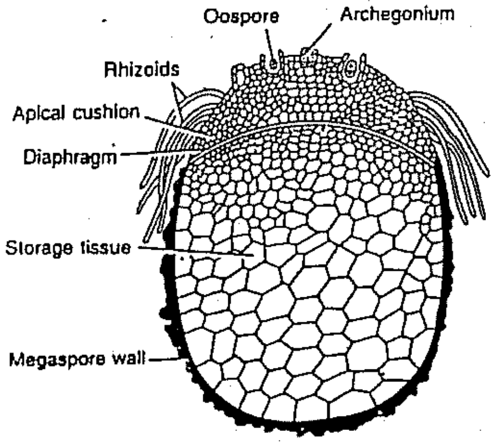

Oospore
Archegonium
Rhizoids
Apical cushion
Diaphragm
Storage tissue
Megaspore wall

Fig. 13.14. A mature female gametophyte of *Selaginella*

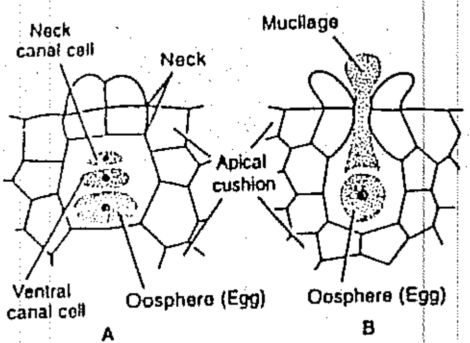

Neck canal cell
Neck
Mucilage
Apical cushion
Ventral canal cell
Oosphere (Egg)
Oosphere (Egg)
A
B

Fig. 13.15. Archegonium of *Selaginella*: A. Young B. Before fertilization

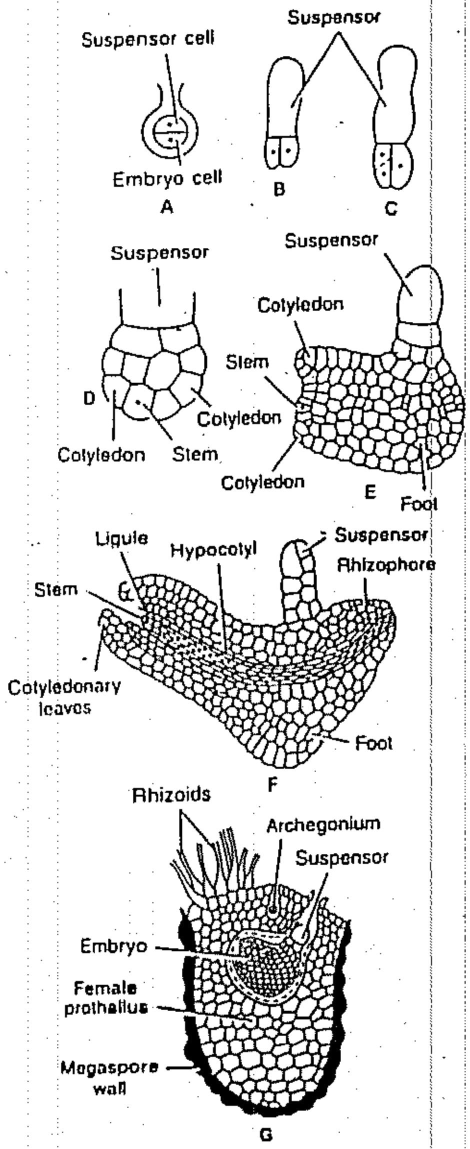

Suspensor cell
Embryo cell
A
Suspensor
B
C
Suspensor
D
Cotyledon
Stem
Cotyledon
Suspensor
Cotyledon
Stem
Cotyledon
E
Foot
Ligule
Hypocotyl
Suspensor
Rhizophore
Stem
Cotyledonary leaves
Foot
F
Rhizoids
Archegonium
Suspensor
Embryo
Female prothallus
Megaspore wall
G

Fig. 13.16. A–G. Development of embryo in *Selaginella*

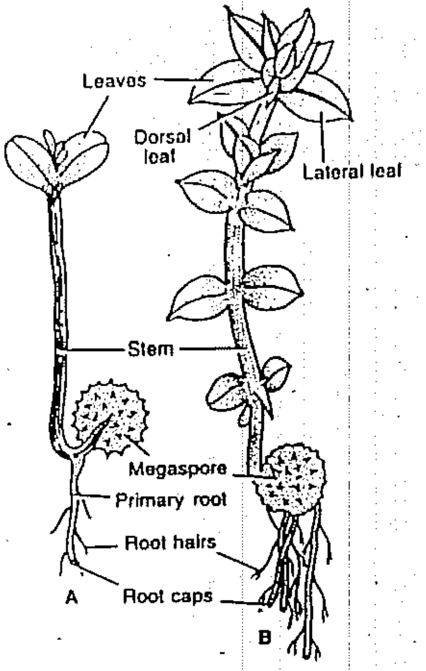

Leaves
Dorsal leaf
Lateral leaf
Stem
Megaspore
Primary root
Root hairs
Root caps
A
B

Fig. 13.17. *Selaginella*: A. Young sporophyte B. Mature sporophyte

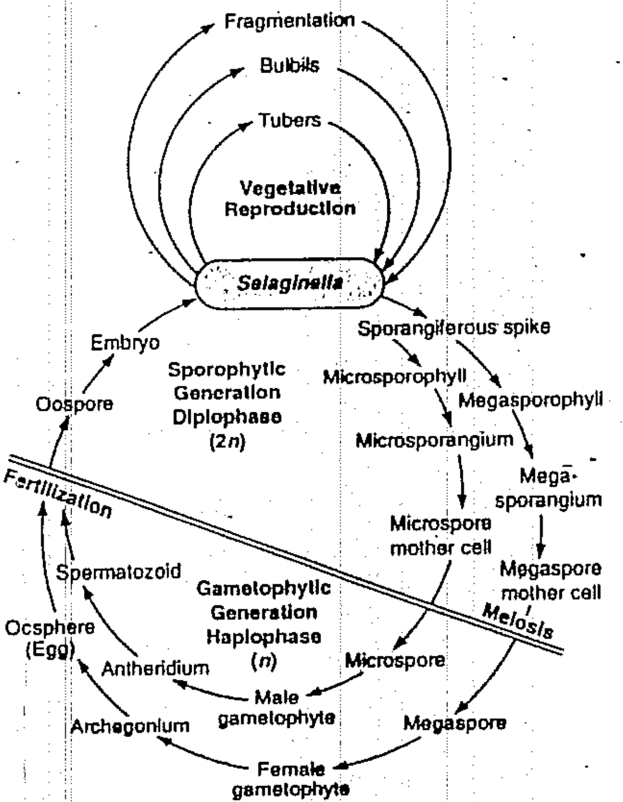

Fragmentation
Bulbils
Tubers
Vegetative Reproduction
Selaginella
Embryo
Sporangiferous spike
Sporophytic Generation Diplophase (2n)
Oospore
Microsporophyll
Megasporophyll
Microsporangium
Mega-sporangium
Fertilization
Microspore mother cell
Megaspore mother cell
Meiosis
Spermatozoid
Gametophytic Generation Haplophase (n)
Ocsphere (Egg)
Antheridium
Microspore
Male gametophyte
Archegonium
Megaspore
Female gametophyte

Fig. 13.18. Graphical representation of life cycle of *Selaginella*

Fertilization

After shedding at 13-celled stage, the microspores complete their development producing **spermatozoids.** These are liberated and if the microspore falls near the mature female gametophyte, the sperms swim from the male gametophyte to reach archegonia and one sperm fuses with egg to form zygote.

- ○ Water is necessary for fertilization and sperms are attracted due to **malic acid.**

Development of embryo or sporophyte

The oospore (zygote) divides transversely into two cells, the upper **epibasal cell** which forms suspensor cell and the **hypobasal cell** which develops into embryo.

The embryo differentiates into foot, root, primary stem with two rudimentary leaves and rhizophore. By growth of stem and the root, the young sporophyte becomes independent of the gametophyte tissue and falls on the ground where the primary rhizophore forms roots that grow into the soil and the plant starts **independent life.**

- ○ There is distinct **heteromorphic alternation of generations** in *Selaginella.*

DRYOPTERIS (FERN)

Systematic position

Division	Filicophyta
Class	Leptosporangiopsida
Order	Filicales
Family	Polypodiaceae
Genus	*Dryopteris*

Fern *Dryopteris filix-mas* is commonly known as **Beech fern** or **Male shield fern** or **Hay scented fern.** There are about 150 sps. and 25 sps. have been reported in India. It is found in sub-tropical regions as well as warm temperate regions.

- *Dryopteris* is commonly found in moist, shady and cool places.

External morphology

Fern plant is sporophytic (2*n*) and is differentiated into roots, stem and leaves. Stem is underground **rhizome** and is generally present obliquely under substratum and only apical portion is outside.

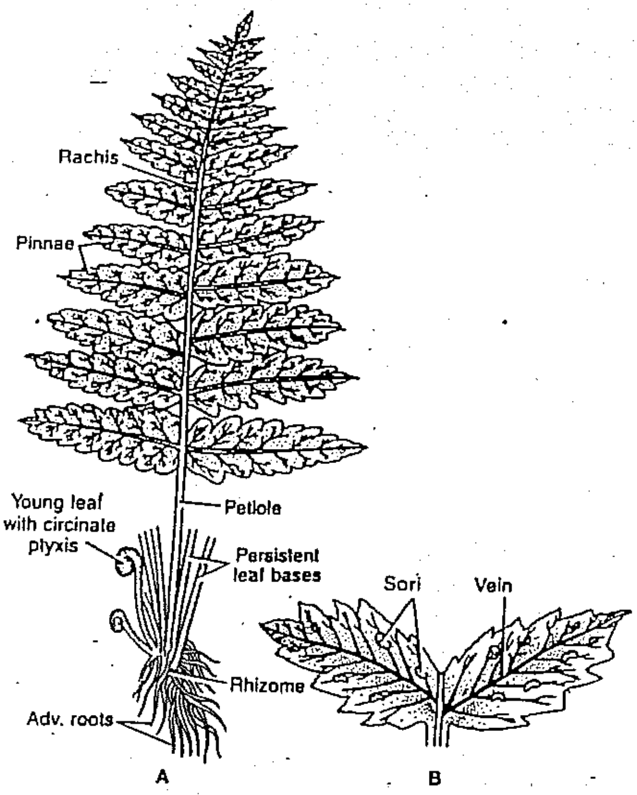


Fig. 13.19. *Dryopteris*: A. Plant showing habit B. Fertile pinnule

- The mature rhizome is beset with **leaf bases,** which make the surface **uneven.** The younger portion of rhizome is covered with **hairy 'ramenta',** which is brown in colour.
- From upper surface of rhizome arise many leaves or fronds. Each leaf is 25 cm to 1 metre in length.
- Leaves are **pinnately compound (bipinnate).**
- On the **rachis,** the pinnae or leaves are arranged in two rows and further in each pinna, there are a number of **pinnules** or **leaflets.** The rachis is also covered with-

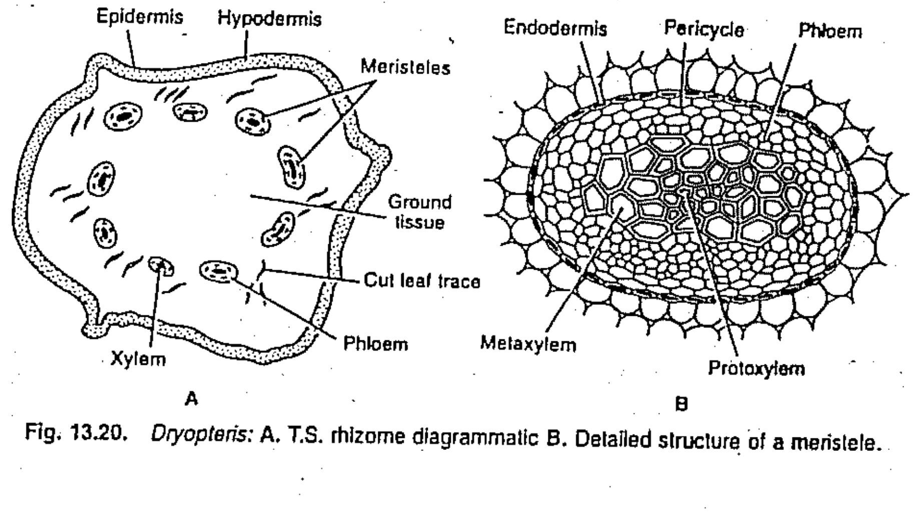


Fig. 13.20. *Dryopteris*: A. T.S. rhizome diagrammatic B. Detailed structure of a meristele.

ramenta. Ramenta provides protection against desiccation and mechanical injury.

- **The vernation or ptyxis is circinate** *(i.e.,* in young condition, leaves are coiled like watch spring or dog tail).
- The venation (arrangement of veins) in leaf is open furcate type.
- On the lower surface of rhizome arises many adventitious roots which help in fixing the plant and also in absorbing minerals and water.

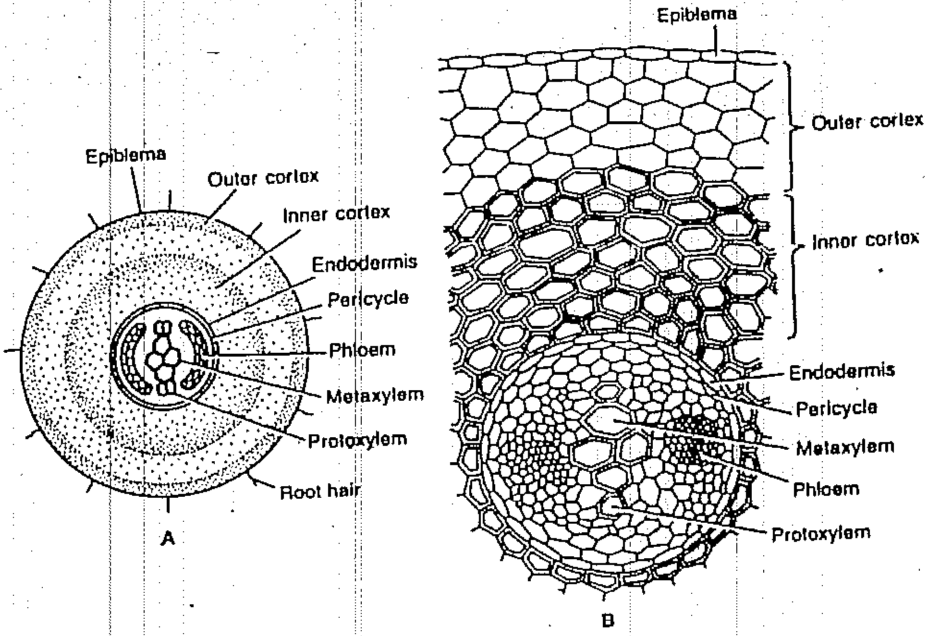

Epiblema
Outer cortex
Inner cortex
Endodermis
Pericycle
Phloem
Metaxylem
Protoxylem
Root hair
A
Epiblema
Outer cortex
Inner cortex
Endodermis
Pericycle
Metaxylem
Phloem
Protoxylem
B

Fig. 13.21. *Dryopteris*: A. T.S. root diagrammatic B. A part cellular

Anatomy

I. Rhizome

The outline of fern rhizome is irregular due to leaf bases. On the outer side is **epidermis**, followed by **hypodermis** and then **cortex**. In the centre is **stele** and stele is **dictyostele**, *i.e.,* vascular cylinder is broken up into a number of smaller units called **meristeles**, which are separated by leaf gaps. Each meristele is having central xylem surrounded by phloem on all sides, *i.e.,* **amphicribal** or **hadrocentric.**

- Xylem is made of tracheids and lacking vessels whereas in phloem companion cells are absent.
- Condition of xylem is mesarch.

II. Root

It is like typical dicot root, *i.e.,* on outer side is single-layered **epiblema** with unicellular root hair. Inner to epiblema is **outer cortex** which is made of thin-walled parenchymatous tissue, followed by **inner cortex** made of sclerenchymatous tissue. Inner to cortex is **endodermis** which is followed by pericycle.

- Xylem is **exarch** and **diarch.**

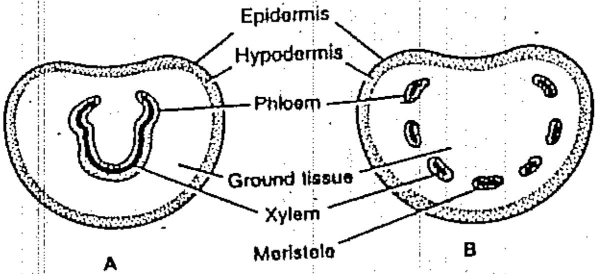

Epidermis
Hypodermis
Phloem
Ground tissue
Xylem
Meristele
A
B

Fig. 13.22. *Dryopteris:* A. T.S. rachis (basal portion) B. T.S. rachis (upper portion)

III. Leaf

2 portions are there in leaf:

(i) Rachis

(ii) Leaf lamina

(i) **Rachis:** In young rachis, vascular cylinder or stele is in the form of **'C' (letter)** which is broken up into meristeles at maturity.

(ii) **Leaf lamina:** It is covered by upper **epidermis** and lower epidermis containing chloroplasts. **Stomata** are present only on lower **epidermis.** Mesophyll is not differentiated into palisade and spongy parenchyma. Although, mesophyll cells below upper epidermis are squarish and compactly arranged whereas in lower portion it is made of irregular cells having intercellular spaces.

- In leaves, larger veins have **concentric** or **bicol-**

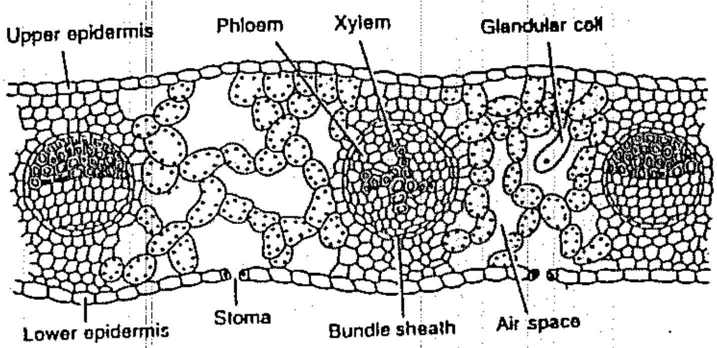

Upper epidermis
Phloem
Xylem
Glandular cell
Lower epidermis
Stoma
Bundle sheath
Air space

Fig. 13.23. V.T.S. of pinnule or sterile leaflet (leaf lamina) of *Dryopteris*

lateral vascular bundles, whereas smaller veins have collateral bundles.

Reproduction

By two methods:

1. Vegetative propagation

Some **adventitious buds** are formed in the axil of leaves and these on separation give rise to new fern plants. It also multiplies vegetatively by **fragmentation** of rhizome.

2. Reproduction by spores

The spores are produced in sporangia. The sporangia are grouped in sori (single sorus).

The sori are produced on ventral surface of leaflets or pinnules. The sori are arranged in 2 rows one on each side of midrib.

- Such fertile leaves having sori or sporangia on them are called **sporophylls.**
- Each sorus is surrounded by a **kidney-shaped** covering called **Indusium.**
- In *Dryopteris,* **true indusium** is present because this arises from placenta or placental tissue, from which sporangia arise. (In *Pteris* false indusium is there because it is formed by leaf margins.)

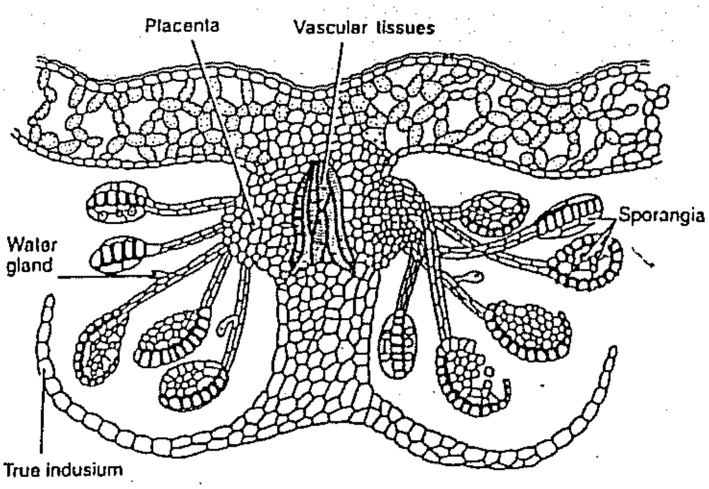

Placenta
Vascular tissues
Sporangia
Water gland
True indusium

Fig. 13.24. V.T.S of leaflet through a sorus

- In the centre of sorus, the vein ends into placental tissue from where arise a number of sporangia.
- The sorus is **mixed** in *Dryopteris* (*i.e.,* no definite arrangement of sporangia).

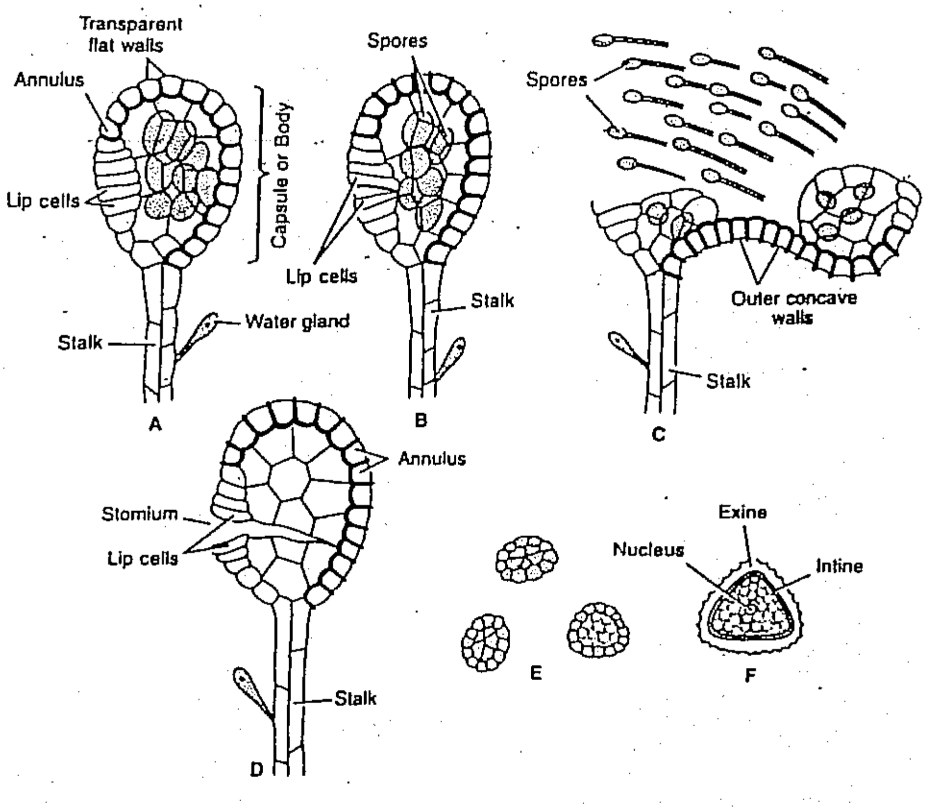

Transparent flat walls
Annulus
Lip cells
Capsule or Body
Water gland
Stalk
A
Spores
Lip cells
Stalk
B
Spores
Outer concave walls
Stalk
C
Annulus
Stomium
Lip cells
Stalk
D
E
Exine
Nucleus
Intine
F

Fig. 13.25. A. Sporangium B–D. Dehiscence of sporangium E–F. spores of *Dryopteris*

Structure of sporangium: The sporangium in *Dryopteris* is having **elongated stalk** made of 3 rows of cells. A water **gland** is present on the stalk. At tip of stalk there is present **biconvex capsule** of sporangium whose wall is single-layered thick. This single vertical row of thick-walled cells present around the sporangium is called **annulus**. The cells of annulus have their **radial and inner walls thicker** and **outer walls thinner**. The annulus is not complete but on one side, there are present few larger, transversely placed, thin-walled cells called **stomium.**

- Inside the sporangium, there are 16 spore mother cells which on reduction division produce 64 spores.
- The spores are small, dusty and having outer brownish, thick **exine** and thinner **intine.**
- Spores are **monolete** and **bilateral** type (*i.e.*, unicellular, uninucleate and bilateral).
- Dehiscence of sporangium occurs in **dry conditions** and annulus is responsible for dehiscence. When conditions are dry, outer thin-walls of annulus are drawn in and pressure is developed, due to which thin stomium cells rupture and dehisced sporangial wall goes backwards like a spring and the spores inside are pushed out with a jerk, (*i.e.*, dehiscence of sporangium occurs through **stomium**).
- When conditions are moist, again the broken wall may come to its original position and again on approach of dry condition, it goes backwards with a jerk and rest of spores are liberated. The spores are alike, *i.e.*, *Dryopteris* is **homosporous.**
- Development of sporangium is **leptosporangiate type.**

Gametophytic generation

On approach of favourable condition, spore germinates. Under suitable temperature and moisture, thick exine ruptures and intine comes out in the form of germ tube.

An apical cell with two cutting faces is formed at the apex and then a **small, green, surface loving, heart-shaped prothallus or prothallium** (gametophyte) is formed.

- The fern prothallus is single celled thick. Although at maturity, the portion below the notch becomes many celled thick, *i.e.*, **cushion.**
- Diameter of fern prothallus is 5 or 6 mm to 13 mm and each cell of prothallus is having **single nucleus** and **many discoid chloroplasts.**
- Fern prothallus is **monoecious** (both **antheridia** and **archegonia**, *i.e.*, male and female sex organs are on the same prothallus). Further it is **protandrous** (antheridia mature first).
- Sex organs are present on ventral or lower side of prothallus.
- Many archegonia are produced on **anterior portion** of prothallus below the notch.
- Antheridia are present on **posterior side** of prothallus intermixed with many unicellular and unbranched **rhizoids.** With the help of rhizoids, the prothallus is attached to substratum and absorbs water and minerals.

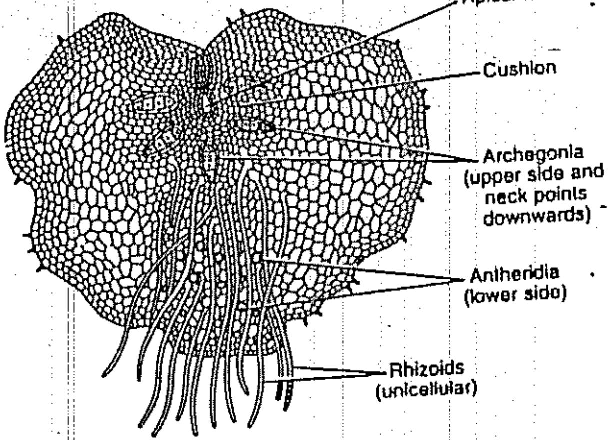


Fig. 13.26. Mature prothallus of *Dryopteris*

- As the fern prothallus is green so it is **autotrophic** and hence **fern prothallus is haploid plant of gametophytic generation** and is **concerned with sexual reproduction.**
- Prothallus may give rise to many daughter prothalli by budding. It is short lived and dies in drought conditions.

Antheridium

Each antheridium is small, sessile and globular structure. Wall of antheridium is having **only 3 cells,** *i.e.*, first ring cell, second ring cell and cover cell.

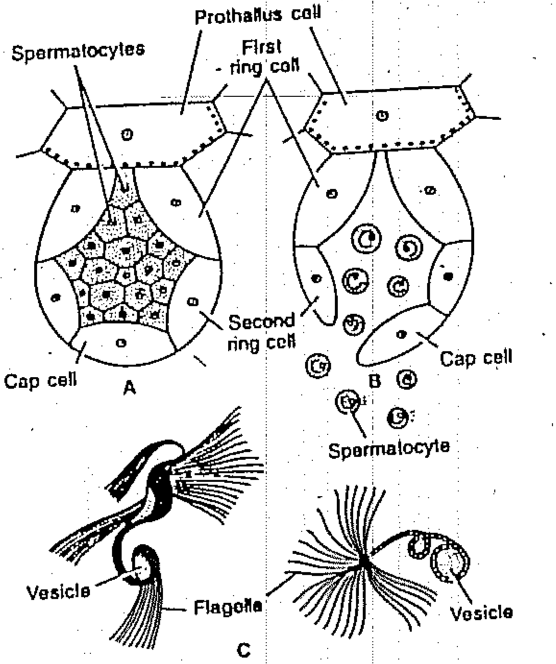


Fig. 13.27. *Dryopteris:* A. L.S. antheridium B. Dehisced antheridium C. Multiflagellate spermatozoids

- Each antheridium is having many (about 32) **multiflagellated**, coiled (2–3 coils) **antherozoids or spermatozoids**. At the posterior end of antherozoid is present a vesicle (unused cytoplasm).

Archegonium

It is a **flask-shaped** structure having venter and neck. Neck is projected out of the prothallus and is **curved posteriorly**. Venter is having basal **large egg cell** and upper small **venter canal cell**. The neck is having **single neck canal cell** but is **binucleate**.

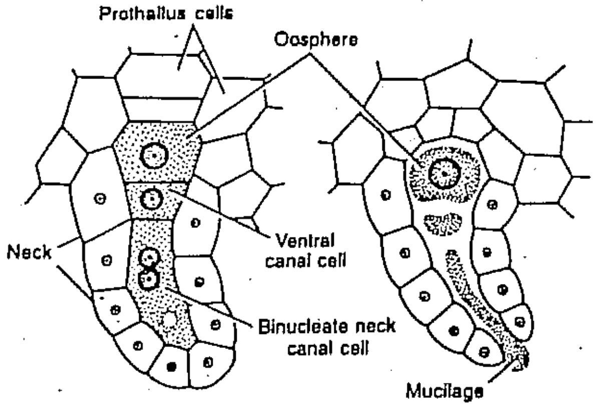

Prothallus cells
Oosphere
Neck
Ventral canal cell
Binucleate neck canal cell
Mucilage

Fig. 13.28. *Dryopteris:* A. Mature archegonium B. Before fertilization

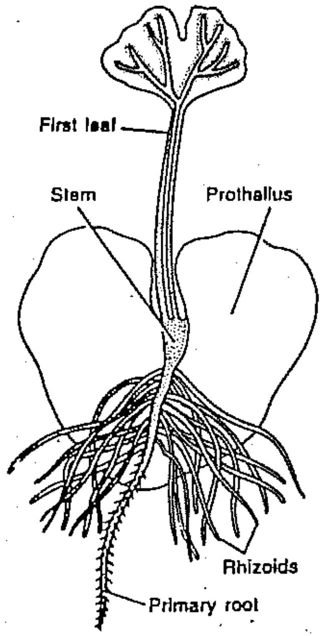

First leaf
Stem
Prothallus
Rhizoids
Primary root

Fig. 13.29. Ventral view of fern prothallus with young sporophyte

- Venter is not having any covering or jacket but neck is surrounded by jacket of 4 vertical rows of cells.

Fertilization and sporophyte development

It occurs when some fluid water is present between prothallus and substratum. On absorbing water, the venter canal cell and neck canal cell disorganise forming **mucilaginous** mass, which is having **malic acid** and due to its **chemotactic** effect, the antherozoids are attracted towards neck of archegonium. A single antherozoid is able to fuse with egg to form zygote ($2n$), which is beginning of sporophytic generation. Zygote divides first by vertical division, followed by another vertical division and **quadrat stage** is formed. Then **octant stage** is formed by transverse division. The foot and root develop from four hypobasal cells and cotyledons as well as stem develop from epibasal cells and thus sporophytic plant is formed.

- Generally a single sporophytic plant develops from single gametophyte or prothallus.
- The fern sporophyte is initially dependent upon gametophyte but later on becomes independent.

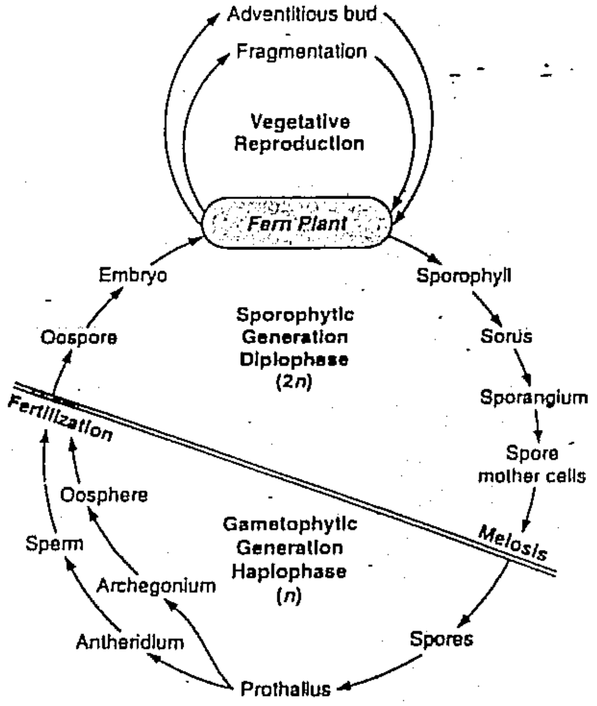

Adventitious bud
Fragmentation
Vegetative Reproduction
Fern Plant
Embryo
Sporophyll
Oospore
Sporophytic Generation Diplophase (2n)
Sorus
Sporangium
Fertilization
Spore mother cells
Oosphere
Meiosis
Sperm
Gametophytic Generation Haplophase (n)
Archegonium
Antheridium
Spores
Prothallus

Fig 13.30. Graphical representation of life cycle of fern *Dryopteris*

MULTIPLE CHOICE QUESTIONS

1. Which plant group is called vascular cryptogams?
(a) Algae (b) Fungi
(c) Bryophyta (d) Pteridophyta

2. Pteridophytes are:
(a) Always herbs
(b) Generally herbs, rarely climbers and trees
(c) Shrubs and trees
(d) Always trees

3. Which is regarded as 'Age of Pteridophytes'?
(a) Mesozoic (b) Proterozoic
(c) Palaeozoic (d) Coenozoic

4. 'Botanical snakes' are:
(a) Algae (b) Bryophytes
(c) Pteridophytes (d) Gymnosperms

5. In which of the following plant is the diploid stage generally dominant?
(a) Algae (b) Fungi
(c) Mosses (d) Ferns

6. Pteridophytes are characterized by:
(a) Presence of vascular tissue
(b) Absence of flowers
(c) Absence of fruits
(d) All of the above

7. Pteridophytes differ from bryophytes in:
(a) Having motile sperms
(b) Having alternation of generation
(c) Having archegonia
(d) Presence of vascular tissue

8. The phloem in pteridophytes is lacking:
(a) Sieve tubes (b) Phloem parenchyma
(c) Companion cells (d) None of these

9. Vessels are present in xylem of:
(a) *Lycopodium* (b) *Selaginella*
(c) *Equisetum* (d) Both (b) and (c)

10. Secondary growth in pteridophytes is:
(a) Absent
(b) Absent except *Isoetes*
(c) Absent except *Selaginella*
(d) Present everywhere

11. Members of pteridophytes are:
(a) Homosporous
(b) Heterosporous
(c) Homosporous or heterosporous
(d) None of the above

12. Spores on germination in pteridophytes give rise to:
(a) Sporophyte (b) Strobilus
(c) Prothallus (d) None of these

13. Which of the following is heterosporous?
(a) *Selaginella* (b) *Salvinia*
(c) *Azolla* (d) All of these

14. Sex organs in pteridophytes are:
(a) Unicellular and jacketed
(b) Multicellular and non-jacketed
(c) Multicellular and jacketed
(d) Unicellular and non-jacketed

15. Number of neck canal cells in archegonium of pteridophytes is:
(a) 2–6 (b) 4
(c) 1 (d) 1–14

16. The spermatozoids in vascular cryptogams are:
(a) Non-flagellated
(b) Biflagellated
(c) Multiflagellated
(d) Biflagellated or multiflagellated

17. Term Alternation of Generations in ferns and mosses was first used by:
(a) Nageli (b) Van Tieghem
(c) Hofmeister (d) Braun

18. The characteristic feature of eusporangiate type of sporangium development is:
(a) Sporangium develops from group of cells
(b) Having multi-layered jacket
(c) Contain large number of spores
(d) All of the above

19. Which pteridophyta group is commonly called club-mosses or spike-mosses?
(a) Psilophyta
(b) Lepidophyta or lycophyta
(c) Arthrophyta or calamophyta
(d) Filicophyta or pterophyta

20. The term 'Stele' was first used by:
(a) Sachs
(b) Kidson and Lang
(c) Van Tieghem and Douliot
(d) Church

21. 'Stele' includes:
(a) Vascular tissue (xylem and phloem)
(b) Pith and vascular tissue
(c) Vascular tissue + pith + pericycle
(d) Vascular tissue + pith + pericycle + endodermis

22. Most primitive type of stele found in pteridophytes is: (CPMT 2001)
(a) Siphonostele (b) Protostele
(c) Solenostele (d) Dictyostele

*23. Which is not part of protostele?
(a) Xylem (b) Phloem
(c) Pith (d) Pericycle

24. Protostele with pith or medullated protostele is called:
(a) Solenostele (b) Siphonostele
(c) Actinostele (d) Plectostele

25. Stele with leaf gap is called:
(a) Cladosiphonic (b) Phyllosiphonic
(c) Haplostele (d) None of these

26. Heterosporous pteridophytes always produce:
(a) Monoecious gametophyte
(b) Dioecious gametophyte
(c) Monothallic gametophyte
(d) None of the above

27. In the formation of siphonostele from protostele, the origin of pith is:
    (a) Intrastelar (b) Extrastelar
    (c) Intrastelar or extrastelar (d) None of these

*28. Megasporophyll of pteridophyte is comparable to which structure of angiosperms?
    (a) Carpel (b) Microsporophyll
    (c) Stamen (d) Ovule

29. Heterospory is production of:
    (a) Sexual and asexual spores
    (b) Large and small spores
    (c) Haploid and diploid spores
    (d) Diploid and tetraploid spores

30. First fossil pteridophyte discovered by Sir William Dawson is:
    (a) *Rhynia* (b) *Horneophyton*
    (c) *Psilophyton* (d) *Asteroxylon*

31. Which is not a fossil pteridophyte?
    (a) *Rhynia* (b) *Horneophyton*
    (c) *Psilophyton* (d) *Gynia*

32. A rootless, leafless pteridophyte from Rhynichert beds, Aberdeenshire (Scotland), *i.e.*; *Rhynia*, was discovered by:
    (a) Sir William Dawson (b) P.N. Mehra
    (c) Kidson and Lang (d) Captain Cooke

33. 'Telome theory' was put forward by:
    (a) Bower (b) Campbell
    (c) Zimmermann (d) Van Tieghem and Douliot

34. Elaboration of simplest sporophyte into modern complex sporophyte is explained by:
    (a) Enation theory (b) Telome theory
    (c) Stelar theory (d) None of these

35. Highest number of chromosomes in plants is observed in a pteridophyte called:
    (a) *Lycopodium* (b) *Osmunda*
    (c) *Ophioglossum* (d) *Marsillea*

36. 'Little club moss' is:
    (a) *Lycopodium* (b) *Selaginella*
    (c) *Equisetum* (d) *Isoetes*

37. 'Horse tail' is:
    (a) *Lycopodium* (b) *Equisetum*
    (c) *Isoetes* (d) *Adiantum*

38. Fern *Adiantum* is known by the common name:
    (a) Quill wort (b) Adder's tongue fern
    (c) Hay-scented fern (d) Maiden hair fern

39. Which is 'walking fern'?
    (a) *Isoetes caromandeliana* (b) *Equisetum volubile*
    (c) *Adiantum caudatum* (d) *Dryopteris filix-mas*

40. Which is a 'rootless fern'?
    (a) *Pteris* (b) *Dryopteris*
    (c) *Salvinia* (d) *Adiantum*

41. Which of the following grows luxuriantly in 'Dal Lake' of Srinagar (Kashmir)?
    (a) *Marsillea* (b) *Adiantum*
    (c) *Salvinia* (d) *Azolla*

42. Which is a xerophytic fern?
    (a) *Marsillea* (b) *Azolla*
    (c) *Woodsia elongata* (d) *Anogramma leptophylla*

43. Smallest fern is:
    (a) *Drynaria* (b) *Anogramma*
    (c) *Cyathaea* (d) None of these

44. Tree fern (tallest pteridophyte) is:
    (a) *Woodsia* (b) *Cyathaea*
    (c) *Drynaria* (d) *Anogramma*

45. Heterospory and seed habit is best evidenced in:
    (a) *Selaginella* (b) *Marsillea*
    (c) *Dryopteris* (d) None of these

*46. Which is 'Resurrection plant'?
    (a) *Marsillea* (b) *Salvinia*
    (c) *Selaginella lepidophylla* (d) None of these

47. *Selaginella* has:
    (a) Dimorphic leaves (b) Isomorphic leaves
    (c) Both (a) and (b) (d) None of these

48. Outgrowth from base of leaves in *Selaginella* is:
    (a) Stipule (b) Ligule
    (c) Velum (d) Trabeculae

49. Leaves in *Selaginella* are:
    (a) Sessile, ovate or lanceolate with acute apex, branched central midrib
    (b) Sessile, ovate or lanceolate with acute apex and central unbranched midrib
    (c) Ovate, subsessile, not with acute apex, without midrib
    (d) None of the above

50. A mature ligule is having a prominent basal portion called: **(PMET Punjab 2003)**
    (a) Protocorm (b) Rhizophore
    (c) Glossopodium (d) Pseudopodium

51. A leafless, colourless, positively geotropic organ that develops from point of bifurcation of stem (angle meristem) in *Selaginella* is:
    (a) Rhizomorph (b) Ramenta
    (c) Ligule (d) Rhizophore

52. *Selaginella* plant is:
    (a) Homosporous (b) Heterosporous
    (c) Isosporous (d) Polysporous

53. Rhizophore of *Selaginella* is:
    (a) Root
    (b) Stem
    (c) New organ or organ sui-generis
    (d) None of the above

54. Rhizophores are unknown in:
    (a) *Selaginella rupestris* (b) *S. kraussiana*
    (c) *S. cuspidata* (d) None of these

55. Root-like character of rhizophore is not:
    (a) Positively geotropic
    (b) Colourless without nodes and internodes
    (c) Monostelic condition
    (d) Exogenous origin

56. Trabeculated endodermis is characteristic of:
    (a) *Lycopodium* (b) *Selaginella*
    (c) *Dryopteris* (d) None of these

57. In *Selaginella* stem, the stele is:
    (a) Monarch and endarch (b) Diarch and exarch
    (c) Diarch and endarch (d) Polyarch and endarch

58. In Rhizophore of *Selaginella*, the stele is:
    (a) Exarch and monarch (b) Endarch and monarch
    (c) Exarch and diarch (d) None of these

59. Which is absent in leaf of *Selaginella*?
(a) Xylem (b) Phloem
(c) Palisade parenchyma (d) Stomata

60. Microsporangia and megasporangia are found on the same strobilus in:
(a) *Adiantum* (b) *Selaginella*
(c) *Dryopteris* (d) None of these

61. Formation of sporophyte from a vegetative portion of prothallus without sexual fusion is called:
(a) Apocarpy (b) Apogamy
(c) Apospory (d) Apomixis

62. Development of sporangium in *Selaginella* is:
(a) Eusporangiate (b) Leptosporangiate
(c) Both (a) and (b) (d) None of these

63. The number of megaspores inside a megasporangium of *Selaginella* is normally:
(a) 16 (b) 8
(c) 4 (d) 2

64. Number of megaspores in *Selaginella rupestris* is:
(a) 1 (b) 2
(c) 4 (d) 3

65. The microspores are shed from the microsporangium of *Selaginella* at:
(a) 8-celled stage (b) Single celled stage
(c) 13-celled stage (d) 4-celled stage

66. The number of antherozoides (male gametes) produced inside the single microspore in *Selaginella* is generally:
(a) 400–1600 (b) 256
(c) 128 (d) 64

67. The antherozoides (male gametes) in *Selaginella* are: (MPPMT 2000)
(a) Multiflagellated (b) Biflagellated
(c) Bi or multiflagellated (d) Non-flagellated

68. Number of prothallial cells in microspore of *Selaginella* is:
(a) 1 (b) 2
(c) 3 (d) 0

69. Number of neck canal cells in archegonium of *Selaginella* is:
(a) 1 (b) 2
(c) 4–6 (d) 1 but binucleate

*70. A peculiar structure called 'embryoschlauch' is found in:
(a) *Selaginella kraussiana* (b) *S. rupestris*
(c) *S. oregana* (d) All of these

71. Development of embryo in *Selaginella* is:
(a) Holoblastic (b) Meroblastic
(c) Both (a) and (b) (d) None of these

72. The phenomenon of vivipary is found in:
(a) *Selaginella kraussiana* (b) *S. rupestris*
(c) *S. lepidophylla* (d) All of these

73. 'Bird's nest moss' is:
(a) *Adiantum* (b) *Marsilea*
(c) *Selaginella lepidophylla* (d) None of these

74. 'Male shield fern' is:
(a) *Dryopteris* (b) *Pteris*
(c) *Adiantum* (d) None of these

75. Fern stele is:
(a) Dictyostele (b) Siphonostele
(c) Protostele (d) Solenostele

76. A non-medullated stele with star-shaped xylem and phloem in patches is:
(a) Protostele (b) Actinostele
(c) Haplostele (d) Siphonostele

*77. Fern prothallus normally is:
(a) Haploid (b) Diploid
(c) Triploid (d) Tetraploid

78. Sorus of *Dryopteris* fern is:
(a) Simple sorus (b) Gradate sorus
(c) Mixed sorus (d) None of these

79. Prothallus of fern produces:
(a) Gametes (b) Spores
(c) Both (a) and (b) (d) None of these

80. Which of the following venation is characteristic of fern?
(a) Parallel (b) Reticulate
(c) Dichotomous (d) Open furcate

81. Rhizome and rachis in fern are covered with:
(a) Hairs (b) Scales
(c) Rhizoids (d) Ramenta

82. Circinate vernation in ferns refers to:
(a) Presence of adventitious roots on rhizome
(b) Attachment of sori on leaf surface
(c) System of leaf gaps in the stem
(d) Leaves are coiled like a spring when young

83. Sporangia and spore bearing leaf in a fern is called:
(a) Ramentum (b) Indusium
(c) Sorus (d) Sporophyll

84. A collection of sporangia attached to placenta and covered over by indusium is called:
(a) Sporophyll (b) Sorus
(c) Cone (d) Ramenta

85. The stele is arranged in the form of 'C' in which portion of fern plant *(Dryopteris)*?
(a) Rhizome (b) Young rachis
(c) Old rachis (d) Lamina

86. The development of sporangium in *Dryopteris* is:
(a) Eusporangiate (b) Leptosporangiate
(c) Both (a) and (b) (d) None of these

87. Sporophyte of *Pteris* is:
(a) Independent of gametophyte from the very beginning
(b) Dependent upon gametophyte only in the beginning
(c) Dependent on gametophyte fully
(d) None of the above

88. Fern *Dryopteris* is:
(a) Homosporous (b) Heterosporous
(c) Both (a) and (b) (d) None of these

89. Spores dissemination in fern *(Dryopteris)* is affected by:
(a) Annulus (b) Indusium
(c) Tapetum (d) Sorus

90. Number of cells in the wall (jacket) of antheridium of *Dryopteris* is:
(a) 1 (b) 2
(c) 3 (d) Many

91. The prothallus of *Dryopteris* is:
(a) Heart shaped (b) Kidney shaped
(c) Lemon shaped (d) Muriform

92. The fern prothallus is:
(a) One cell thick (b) 4-cells thick
(c) Many cells thick (d) None of these

93. The sex organs are present on which surface of fern prothallus?
(a) Dorsal (b) Ventral
(c) Both (a) and (b) (d) None of these

94. The prothallus of *Dryopteris* is:
(a) Dioecious
(b) Monoecious and protogynous
(c) Monoecious and protandrous
(d) None of the above

95. The antherozoides in *Dryopteris* are:
(a) Biflagellated with a single coil
(b) Biflagellated with 2–3 coils
(c) Multiflagellated with 2–3 coils
(d) Multiflagellated with a single coil

96. The sex organs that develop on surface of prothallus of *Dryopteris* intermingled with rhizoids are:
(a) Antheridium (b) Archegonium
(c) Ascogonium (d) None of these

97. In the archegonium of *Dryopteris*:
(Orissa JEE 2002; MH-CET 2003)
(a) There are 4 neck canal cells
(b) 3 neck canal cells
(c) One neck canal cell with single nucleus
(d) One neck canal cell with 2 nuclei

*98. Which is not involved in the fertilization of fern?
(a) Water (b) Archegonia
(c) Flagellated sperms (d) Pollen tube

99. Gametangia of fern are produced on:
(a) Leaves (b) Sorus
(c) Prothallus (d) Ramenta

100. Usually how many sporophytes are developed out of a gametophyte (prothallus) of *Dryopteris*?
(a) 1 (b) 2
(c) 4 (d) 3

101. Which wall is thicker in annulus cells of sporangium of fern *(Dryopteris)*?
(a) Radial (b) Outer and inner
(c) Radial and inner (d) Outer and radial

102. The main plant body of *Selaginella* species is:
(MPPMT 1997)
(a) Gametophyte (b) Sporophyte
(c) Both (a) and (b) (d) Halophyte

*103. Which pteridophyte is of medicinal importance?
(a) *Isoetes* (b) *Lycopodium*
(c) *Selaginella* (d) *Rhynia*

104. Number of spores in sporangium of fern are:
(AFMC 1996)
(a) 64 (b) 32
(c) 16 (d) 128

105. Trabeculae in *Selaginella* represent modified:
(MPPMT 1993, 2000)
(a) Endodermal cells (b) Pericycle cells
(c) Inner cortical cells (d) Phloem cells

106. Actinostele is related to:
(a) Dictyostele (b) Siphonostele
(c) Solenostele (d) Protostele

107. Pteridophytes are also called:
(a) Cryptogams
(b) Vascular cryptogams
(c) Amphibians of the plant kingdom
(d) Phanerogams

108. Microsporangia and megasporangia are found in the same strobilus in:
(a) *Selaginella* (b) *Dryopteris*
(c) *Adiantum* (d) *Pinus*

109. Fern stele is a:
(a) Protostele (b) Siphonostele
(c) Dictyostele (d) None of these

110. Sporophyte of *Pteris*:
(a) Supplies water and inorganic salts to the gametophyte
(b) Is independent of gametophyte from the very beginning
(c) Is dependent on the gametophyte only in the beginning
(d) None of the above

*111. *Selaginella* shows character of evolutionary importance and that character is the presence of:
(a) Ligule (b) Heterosporous condition
(c) Rhizophore (d) Strobilus

112. *Ulothrix*, *Riccia* and fern are similar in having:
(a) Dominant gametophyte
(b) Unicellular gametangia
(c) Absence of vascular tissues
(d) Presence of flagellated gametes

113. The neck of fern archegonium is:
(a) Short and curved (b) Long and straight
(c) Long and curved (d) Short and straight

114. Fern prothallus is: **(CPMT 1993; Manipal 2003)**
(a) Heterotrophic (b) Heteromorphic
(c) Homothallic (d) Heterothallic

115. *Selaginella* differs from *Pteris* in which of the following characters?
(a) Heterosporous condition
(b) Absence of seed
(c) Absence of vessels in xylem
(d) Need of water for fertilization

116. Microsporophyll of pteridophytes is comparable to which structure of angiosperms?
(a) Stamen (b) Ovule
(c) Leaf (d) Carpel

117. Rhizophore of *Selaginella* is:
(a) Root stock (b) Organ sui-generis
(c) Stem tuber (d) Leaf

118. Pteridophytes differ from bryophytes in having:
(CPMT 1991)
(a) Independent gametophyte and sporophyte
(b) Sporophyte dependent on gametophyte
(c) Gametophyte dependent on sporophyte
(d) Absence of sporophyte

119. Polystelic stem is seen in:
(a) *Cycas* (b) *Riccia*
(c) *Selaginella* (d) *Funaria*

120. In which of the following plants, the diploid stage generally dominates?
(a) Algae (b) Fungi
(c) Mosses (d) Fern

121. Spore dissemination in many ferns is affected by:
(a) Indusium (b) Sorus
(c) Annulus (d) Tapetum

122. Which of the following structures are functionally not similar to others?
(a) Antheridium (b) Oogonium
(c) Archegonium (d) Ovum

123. The sori of *Pteris* are:
(a) Discontinuous and kidney-shaped
(b) Discontinuous and vermiform
(c) Discontinuous and rounded
(d) Continuous and linear

124. The stele in the rachis of *Dryopteris* is:
(a) Protostelic (b) Siphonostelic
(c) Dictyostelic (d) Haplostelic

125. Sometimes prothallus of a fern gives rise to a fern plant; it is an example of:
(a) Parthenocarpy (b) Apospory
(c) Apogamy (d) Parthenogenesis

126. A fern differs from a moss in having:
(a) Swimming archegonia
(b) Swimming antherozoids
(c) An independent gametophyte
(d) An independent sporophyte

127. *Selaginella* differs from moss in having:
(a) Swimming antherozoids
(b) An independent gametophyte
(c) Archegonia
(d) Well developed vascular system

128. What represents the gametophytic generation in pteridophytes? **(CPMT 1992)**
(a) Main plant body
(b) Heart-shaped prothallus
(c) Structure surrounded by kidney-shaped indusium
(d) Stomium

129. Pteridophytes differ from moss in having:
(a) Swimming antherozoids
(b) Well developed vascular system
(c) Archegonia
(d) An independent gametophyte

130. Heterospory and ligulate leaves are features of: **(BHU 1992)**
(a) *Selaginella* (b) Ferns
(c) All bryophytes (d) All pteridophytes

131. In *Selaginella*, reduction division occurs: **(CBSE 1992)**
(a) During formation of microspores
(b) During formation of both microspores and megaspores
(c) During formation of sperms
(d) Immediately after fertilization

132. The fern rhizome is: **(CPMT 1991)**
(a) Root (b) Stem
(c) Rhizoid (d) Rhizophore

133. In a fern, *e.g., Dryopteris*, spores are formed in:
(a) Oogonium (b) Archegonium
(c) Stomium (d) Sporangium

134. Which of the following is not involved in the fertilization of ferns? **(CPMT 1990)**
(a) Pollen tube (b) Water
(c) Archegonia (d) Flagellated sperms

135. In *Pteris*, the flagella of antherozoids are attached to:
(a) Body surface (b) Nucleus
(c) Blepharoplast (d) Centrosome

*136. Gametangia of fern are produced on:
(a) Sorus (b) Prothallus
(c) Ramenta (d) Leaves

137. In *Lycopodium*, the stele is:
(a) Siphonostele (b) Meristele
(c) Polystele (d) Protostele (actinostele)

138. Formation of sporophyte from a vegetative portion of prothallus (or from gametophyte) without sexual fusion is called:
(a) Apogamy (b) Apomixis
(c) Apocarpy (d) Apospory

139. The sporangia of eusporangiate ferns: **(BHU 1990)**
(a) Possess a single layer of wall cells
(b) Produce very few spores
(c) Originate from a group of initial cells
(d) Dehisce at the region of well-defined stomium

140. Sporangia-bearing leaf is called as:
(a) Sporophyll (b) Ramentum
(c) Indusium (d) Sorus

141. According to available fossil records which of the following are the first land vascular plants?
(a) Cycads (b) Lycopsids
(c) Psilophytales (d) Horsetails

142. In ferns, sporangia are borne on the: **(CPMT 1992)**
(a) Margins of leaf (b) Abaxial surface of leaf
(c) Adaxial surface of leaf (d) Only on the tip of leaf

143. Which of the following is called walking fern? **(Raj. PMT 1991)**
(a) *Ophioglossum* (b) *Pteris*
(c) *Pteridium* (d) *Adiantum*

144. In *Dryopteris*, the antherozoids are:
(a) Multiflagellate spirally coiled
(b) Multiflagellate sickle-shaped
(c) Biflagellate sickle-shaped
(d) Biflagellate spirally coiled

145. A sporangium of fern is:
(a) Many-celled and formed by many cells
(b) One-celled and formed by a single cell
(c) Many-celled and formed by a single cell
(d) One-celled and formed by many cells

146. Pteridophytes as a group differ from bryophytes in the: **(CBSE 1993; BHU 2000; CPMT 2000)**
(a) Motile sperms
(b) Presence of vascular tissue
(c) Archegonia
(d) Alternation of generations

147. Seed habit originated in:
(a) Algae (b) Fungi
(c) Bryophytes (d) Pteridophytes

148. Prothallus represents the:
(a) Sporophytic phase in angiosperms
(b) Sporophytic phase in gymnosperms

(c) Gametophytic phase in ferns
(d) Sporophytic phase in ferns

149. Megasporophyll of *Selaginella* is comparable to which structure of angiosperms? (BHU 1991)
(a) Carpel (b) Stamen
(c) Ovule (d) Leaf

150. Meristeles are found in:
(a) *Pinus* needle (b) *Cycas* stem
(c) Fern rhizome (d) Fern leaf

*151. The annulus of sporangium of the fern assists in the dispersal of spores by:
(a) Collapsing in the strong wind
(b) Losing the air of its cells
(c) Losing water from its cells
(d) Taking up water from air

152. Fern prothallus normally is:
(a) Haploid (b) Diploid
(c) Triploid (d) Tetraploid

153. In *Pteris*, the sori are:
(a) Continuous and linear
(b) Discontinuous and circular
(c) Discontinuous and reniform
(d) Discontinuous and vermiform

154. Spores of *Dryopteris* are:
(a) Haploid (b) Diploid
(c) Triploid (d) Tetraploid

155. The gametophytic and sporophytic generations are featured in the life histories of:
(a) Parasitic fungi (b) Brown algae
(c) Ferns (d) Green leaf

156. Spores of a fern represent:
(a) Sporophytic stage
(b) Gametophytic stage
(c) Sporophytic and gametophytic stage
(d) Apomictic stage

157. In pteridophytes, reduction division occurs when:
(a) Prothallus is formed (b) Sex organs are formed
(c) Spores are formed (d) Gametes are formed

158. The pteridophyte which is called stag's horn fern is: (MDAT Bihar 1991)
(a) *Platycerium* (b) *Botryopteris*
(c) *Salvinia* (d) *Azolla*

159. Which of the following is a fossil?
(a) *Selaginella* (b) *Pteris*
(c) *Rhynia* (d) *Psilotum*

160. *Azolla* is a:
(a) Bryophyte (b) Alga
(c) Fungus (d) Water fern

161. In *Selaginella*, male gametes are:
(a) Multiflagellate (b) Aflagellate
(c) Biflagellate (d) Monoflagellate

162. Sori in ferns are found on:
(a) Stomium (b) Sporophylls
(c) Capsule (d) Placenta

163. The place or point where sporangium of a fern bursts is (or the place of dehiscence in the sporangial wall of *Dryopteris* is known as):
(a) Annulus (b) Stomium
(c) Ostiole (d) Operculum

164. What is the basis of broad classification of filicales?
(a) Nature of annulus
(b) Nature of sporophyll and sporangia
(c) Sori
(d) Nature of indusium

165. An amphiphloic siphonostele shows:
(a) Phloem present on the outer side of xylem only
(b) Phloem present on both outer and inner side of xylem in a tubular stele
(c) Phloem is in the centre and surrounded by xylem
(d) Phloem present on the inner side of xylem only

166. What happens to the spore of ferns?
(a) It germinates to become another spore forming a fern plant
(b) It germinates to become a prothallus
(c) It joins with another spore to form a seedling
(d) None of the above

167. The antherozoids of *Selaginella* are: (CBSE 1990)
(a) Elongate and biflagellate
(b) Elongate and multiflagellate
(c) Oval and biflagellate
(d) Oval and multiflagellate

168. In ferns, circinate vernation refers to:
(a) Arrangement of leaf gaps in stems
(b) Coiling of young leaves
(c) Presence of adventitious roots
(d) Attachment of sori on leaf surface

169. Most primitive living vascular plants are:
(a) *Sphagnum* (b) Cycads
(c) Brown algae (d) Ferns

170. Structures that produce gametes in prothallus are:
(a) Antheridia and archegonia
(b) Ascogonium and anthers
(c) Anthers and archegonia
(d) None of the above

171. The leaf gap in the vascular cylinder in fern is: (CPMT 1990)
(a) Air space
(b) Parenchymatous zone
(c) Collenchymatous zone
(d) Area exclusively of phloem

172. The number of male prothallial cells in *Selaginella* are: (MPPMT 1993)
(a) One (b) Two
(c) Four (d) Nil

173. Which of the following is the prothallus of fern?
(a) Gametophyte (b) Sporophyte
(c) Dikaryotic (d) Diploid

174. Meiosis occurs in the formation of reproductive structures in:
(a) Prothallus (b) Protonema
(c) Fern sporangium (d) Promycelium

175. A feature common to gametophytes and sporophytes of mosses and ferns respectively is: (BHU 1990)
(a) Independent existence (b) Autotrophic nutrition
(c) Unbranched habit (d) Branched habit

*176. One character common to all pteridophytes is:
(a) Heterospory
(b) Leptosporangiate sporangia
(c) Protostelic stele
(d) Absence of ovules

177. In fern, we find:
(a) Sori on dorsal surface (b) Epiphyllous buds
(c) Coiled vernation (d) Circinate vernation

178. Prothallus of fern produces: (BHU 1990)
(a) Spores (b) Gametes
(c) Both (a) and (b) (d) None of these

179. Distinction of root, stem and leaf primodia in a developing fern occurs in the:
(a) Sporangium
(b) Zygote
(c) Four celled stage of the embryo
(d) Antheridium

180. In *Dryopteris*, flagella of spermatozoids are attached to:
(a) Cell nucleus (b) Blepharoplast
(c) Rhizoplast (d) Body surface

181. *Pteris* differs from *Funaria* in having:
(a) Dependent sporophyte
(b) An independent gametophyte
(c) Swimming antherozoids
(d) Dominant sporophytic phase

182. The sperm of fern is: (CPMT 1992)
(a) Biciliate (b) Multiciliate
(c) With only one flagella (d) Smooth surface

183. Sporophyte of fern produces:
(a) Pollen (b) Spores
(c) Seeds (d) None of these

184. Fern differs from *Selaginella*:
(a) In having rhizoids
(b) In absence of heterosporous condition
(c) In arrangement of leaves
(d) None of the above

185. The formation of gametophyte-like structure from a sporophyte without spore formation is known as:
(a) Parthenogenesis (b) Azygospore
(c) Apospory (d) Apogamy

186. In ferns, the xylem is:
(a) Exarch (b) Mesarch
(c) Endarch (d) Polyarch

187. One character is common for *Selaginella* and ferns:
(a) Stele is protostele
(b) Absence of ovules
(c) Presence of heterosporous condition
(d) Development of sporangium

188. Multiflagellate male gametes or sperms are found in: (CPMT 1993)
(a) *Funaria* (b) *Dryopteris*
(c) *Riccia* (d) *Chlamydomonas*

189. The stele in the rachis of *Pteris* is:
(a) Collar-shaped (b) Horse shoe-shaped
(c) Omega-shaped (d) H-shaped

190. Which of the following does not have a certain pith?
(a) Protostele (b) Solenostele
(c) Siphonostele (d) Dictyostele

191. Young sporophyte of *Pteris* fern draws nourishment from prothallus through: (CPMT 1993)
(a) Root (b) Rhizoid
(c) Foot (d) Haustoria

192. The fern *Dryopteris* is characterized by which of the following features?
(a) Heterosporous (b) Homosporous
(c) Seed bearing (d) Tracheids and vessels

193. Two distinct separate generations in single life cycle are seen in:
(a) Mango (b) *Pteris*
(c) *Spirogyra* (d) *Bacillus*

194. The spores in *Dryopteris* are:
(a) Unicellular and isobilateral
(b) Multicellular and uninucleate
(c) Unicellular and uninucleate
(d) None of the above

195. The distinct alternation of generations is found in:
(a) *Ulothrix* (b) *Pteris*
(c) *Rhizopus* (d) *Mucor*

196. What may be the possible advantage accruing out of the presence of antheridia and archegonia on the under side of a fern prothallus?
(a) They are protected from direct rays of sun
(b) Capillary water accumulates on the underside of the prothallus between its lower surface and the soil surface. Sex organs projecting in this water can be readily fertilized by the ciliated sperms which are chemotactically attracted by the archegonia
(c) The sex organs are protected from the wind
(d) Nutrients manufactured by the green prothallus can readily step downwards to the sex organs due to the action of gravity

*197. When sperms of *Funaria* and *Pteris* are put together near the archegonia of *Pteris*, only the sperms of *Pteris* readily enter the archegonia and reach the egg, the reason being that:
(a) Sperms of *Funaria* are killed when mixed with sperms of *Pteris*
(b) Archegonia of *Pteris* secrete a substance which repels sperms of *Funaria*
(c) Archegonia of *Pteris* secrete a chemical substance which attracts sperms of *Pteris* chemotactically
(d) Sperms of *Funaria* are less motile

198. The kidney-shaped structure covering the sorus in *Dryopteris* is called: (CPMT 1990)
(a) Placenta (b) Ramentum
(c) Sporophyll (d) Indusium

199. *Selaginella* is also known as:
(a) Bog moss (b) Lichen
(c) Peat moss (d) Resurrection plant

200. The leaf tips of fern plant are modified into: (CPMT 1992)
(a) Prickles
(b) Tendrils
(c) Ramenta
(d) Circinately coiled structure

201. Which among the following is considered advanced among pteridophytes? (MDAT Bihar 1990)
(a) Club mosses (b) Ferns
(c) Quillworts (d) Scouring rushers

202. In *Selaginella* the glossopodium is present on:
(a) Root (b) Rhizophore
(c) Stem (d) Leaf

203. The rhizophore is not a true root because it is: (MDAT Bihar 1997)
(a) Endogenous (b) Exogenous
(c) Mesogenous (d) Endarch

204. The pteridophyte, popularly known as 'Quillwort' and 'Merllyns grass' is: (EAMCET 1990)
(a) *Isoetes* (b) *Marsillea*
(c) *Lycopodium* (d) *Selaginella*

205. Antherozoid attractant in an archegonial ooze of fern is:
(a) Sugar (b) Amino acid
(c) Malic acid (d) Mucilage

206. The most important characteristics of a fern plant is:
(a) Circinate pinnules (b) Photosynthetic sporophyll
(c) Compound leaves (d) Spores in sporangia

207. Which of the following venation is characteristic of fern?
(a) Parallel (b) Reticulate
(c) Open furcate (d) Closed dichotomous

208. The stele of *Pteridium* root is: (Raj. PMT 1992)
(a) Diarch exarch (b) Diarch endarch
(c) Polyarch exarch (d) Polyarch endarch

209. A stele having leaf gaps to produce many smaller meristeles is known as:
(a) Dictyostele (b) Solenostele
(c) Siphonostele (d) All of these

210. Sorus bearing leaf of *Pteridium* is called:
(a) Ramenta (b) Indusium
(c) Sporophyll (d) None of these

211. Indusium in *Pteridium* is:
(a) Outer true and inner false
(b) Only true
(c) Outer false and inner true
(d) Only false

212. Spores of fern are:
(a) Haploid (b) Diploid
(c) Triploid (d) Polyploid

213. Sporophyte of *Pteridium* is:
(a) Dependent on gametophyte
(b) Dependent on embryo
(c) Dependent on prothallus
(d) Independent

214. Ligule in leaf of *Selaginella* is present on surface:
(a) Abaxial (b) Adaxial
(c) Abaxial or adaxial (d) None of these

215. What is produced from the fertilization of egg in fern?
(a) Ascospore (b) Zygospore
(c) Oospore (d) None of these

216. Which is epiphytic sps. of *Selaginella*?
(a) *Selaginella kraussiana* (b) *S. chrysocaulous*
(c) *S. oregena* (d) All of these

217. In which pteridophyte, apospory was first observed?
(a) *Lycopodium* (b) *Isoetes*
(c) *Selaginella* (d) *Athyrium*

218. Fern plant is a: (MPPMT 1995)
(a) Haploid gametophyte (b) Diploid gametophyte
(c) Diploid sporophyte (d) Haploid sporophyte

219. The stem of *Selaginella* is automatically characterised by the presence of: (MPPMT 1994)
(a) Siphonostele
(b) Amphiphloic siphonostele
(c) Ectophloic siphonostele
(d) Protostele

220. A plant having vascular supply, producing spores but lacking seeds is a: (BHU 1995, 2000)
(a) Bryophyte (b) Pteridophyte
(c) Gymnosperm (d) Angiosperm

221. A fern is a:
(a) Vascular non-flowering plant
(b) Non-vascular non-flowering plant
(c) Vascular flowering plant
(d) Non-vascular flowering plant

222. If the number of chromosomes in the foot of a fern embryo is 8, what should be the number in its spore? (Manipal 2003)
(a) 4 (b) 8
(c) 16 (d) 23

223. The cells of fern prothallus contain nucleus with:
(a) 4-n chromosomes (b) 3-n chromosomes
(c) 2-n chromosomes (d) n chromosomes

*224. The first seed plants appeared during which period? (AMU 1996)
(a) Silurian (b) Devonian
(c) Carboniferous (d) Cretaceous

225. Seed habit first originated in: (AMU 1997)
(a) Certain ferns (b) Certain pines
(c) Certain monocots (d) Certain dicots

226. Which of the following plants exhibit independent alternation of generation? (Pondicherry 1996)
(a) Angiosperms (b) Gymnosperms
(c) Pteridophytes (d) Bryophytes

227. In which of the following rocks the earlier vascular plants have been discovered? (Pb. PMT 1997)
(a) Early cambrian (b) Early devonian
(c) Mid cretaceous (d) Silurian

228. While entering the neck of a fern archegonium, sperms show: (CET Chandigarh 1997)
(a) Phototaxy (b) Chemotaxy
(c) Thermotaxy (d) Cyclosis

229. Chlorophyll and chloroplast are present in spores of: (AIIMS 1997)
(a) *Lycopodium* (b) *Chemotaxy*
(c) *Dryopteris* (d) *Marsillea*

*230. Which of the following pteridophytes shows the chloroplast having pyrenoids? (DPMT 1997)
(a) *Equisetum* (b) *Selaginella*
(c) *Pteridium* (d) *Marsillea*

231. Which of the following has amphiphloic siphonostele? (CET Chandigarh 1997)
(a) Rhizome of *Marsillea* (b) Stem of *Lycopodium*
(c) Rhizome *of Pteris* (d) Stem of *Equisetum*

232. Heterospory and seed habit are often discussed in relation to a structure called: (CBSE 1997)

(a) Spathe (b) Bract
(c) Petiole (d) Ligule

*233. Botanical name of Sanjeevani or Hasnpari is: (BHU 1997)
(a) *Selaginella bryopteris* (b) *S. chrysocaulous*
(c) *S. kraussiana* (d) *S. pallidissima*

234. 'Maiden hair fern' is: (AMU 1997)
(a) *Dryopteris* (b) *Azolla*
(c) *Adiantum* (d) *Pteris*

235. The rudimentary seed habit has been attained in: (Manipal 1997)
(a) *Psilotum* (b) *Lycopodium*
(c) *Selaginella* (d) *Equisetum*

236. Main plant of *Selaginella* species is: (MPPMT 1997)
(a) Gametophyte (b) Sporophyte
(c) Both (a) and (b) (d) Halophytes

237. Sporocarp is a reproductive structure of: (BHU 1996)
(a) Some algae
(b) Some aquatic ferns having sori
(c) Angiosperms having spores
(d) Bryophytes

238. Protostele is: (BHU 1996)
(a) Stele divided into many parts
(b) Early stele with central solid xylem surrounded by phloem
(c) Latent stele
(d) Angiosperm stele

239. Polystelic condition is found in: (BHU 1997)
(a) Rachis of *Pteris*
(b) Roots of *Dryopteris*
(c) Stem of all species of *Selaginella*
(d) Stem of *Selaginella willdenowii*

240. The vascular supply given from the main stele for leaf is called:
(a) Leaf gap (b) Leaf trace
(c) Branch trace (d) Haplostele

241. If a sporangium is derived from a single cell, it is called: (BHU 1997)
(a) Leptosporangiate (b) Eusporangiate
(c) Heterosporangiate (d) None of these

242. Indusium is found in: (CPMT 1998)
(a) Fungi (b) Moss
(c) Algae (d) *Pteris*

243. The walking fern is so named because: (CBSE 1998)
(a) Its spores are able to walk
(b) It is dispersed through the agency of walking animals
(c) It propagates vegetatively by its leaf tips
(d) It knows how to walk by itself

244. Prothallus means: (BHU 1999)
(a) Immature gametophyte (b) Immature sporophyte
(c) Immature archegonium (d) None of these

245. Which one of the following is the earliest land plant? (BHU 2000)
(a) *Cordaites* (b) *Cooksonia*
(c) *Hornea* (d) *Rhynia*

246. In ferns, meiosis occurs during: (CBSE 2000)
(a) Spore formation (b) Gamete formation
(c) Antheridia formation (d) All of these

247. A pteridophyte which fixes N_2 is: (CBSE 2000, 2001)
(a) *Azolla* (b) *Salvinia*
(c) *Pteris* (d) *Selaginella*

248. In ferns, archegonia are found on: (CPMT 2001)
(a) Prothallus (b) Leaves
(c) Stem (d) Sporangia

249. Large leaves of ferns are called fronds which are: (CPMT 2001)
(a) Reproductive (b) Vegetative
(c) Foliage (d) All of these

250. Pteridophytes are characterized by: (Manipal 2001)
(a) Dominant sporophytic generation
(b) Dominant gametophytic generation
(c) Formation of leafy gametophore as dominant generation
(d) None of the above

251. Pteridophytes differ from bryophytes in having: (Uttaranchal PMT 2001)
(a) Independent sporophyte (b) Dependent sporophyte
(c) No vascular bundles (d) None of these

*252. Structure present over the leaves of ferns is called: (Uttaranchal PMT 2001)
(a) Ramenta (b) Fronds
(c) Spathe (d) Indusium

*253. Coal is formed by: (AFMC 2000)
(a) Pteridophytes (b) Bryophytes
(c) Fungi (d) Bacteria

*254. The 13-celled male gametophyte in *Selaginella* is: (AIIMS 2000; BHU 2001)
(a) 12-cells of antheridium + 1-prothallial cell
(b) 10-cells of antheridium + 3-prothallial cells
(c) 9-cells of antheridium + 4-prothallial cells
(d) 7-cells of antheridium + 6-prothallial cells

255. Sometimes the prothallus of a fern gives rise to a fern plant without any fertilization. This is an example of: (AIIMS 2001)
(a) Apospory (b) Apogamy
(c) Parthenocarpy (d) Parthenogenesis

256. Polystelic condition is found in: (CPMT 2002)
(a) Rachis of *Pteris*
(b) Roots of *Dryopteris*
(c) Stem of all species of *Riccia*
(d) Stem of *Selaginella laevigata*

257. Vascular strands in rhizome of *Pteridium* are: (CPMT 2002)
(a) Collateral open (b) Bicollateral open
(c) Concentric amphivasal (d) Concentric amphicribal

258. 'Club moss' is the common name of: (Raj. PMT 2001)
(a) *Lycopodium* (b) *Selaginella*
(c) *Funaria* (d) *Potamogeton*

259. In fern, gametophyte is: (Raj. PMT 2001)
(a) Main plant body
(b) Prothallus attached to the sporophyte
(c) Prothallus free from sporophyte
(d) A structure attached to the rhizome

260. In *Selaginella*, a member of Pteridophytes, heterosporous spores are: (BHU 2002)

(a) Large and small (b) Haploid and diploid
(c) Asexual and sexual (d) All spores of same size

261. The brown hairs present at the base of the petiole of *Pteris* are called: (EAMCET 2002)
(a) Setae (b) Ramenta
(c) Spines (d) Stipules

262. Protosteles are found in: (MPPMT 2002)
(a) Bryophyta (b) Gymnosperms
(c) Pteridophyta (d) Angiosperms

263. In rhizome of *Pteridium*, stele which is composed of two or more than two concentric rings of vascular bundles, is called: (Raj. PMT 2002)
(a) Polycyclic (b) Siphonostele
(c) Ectophloic siphonostele (d) Cladosiphonostele

264. Which one of the following is not found in *Selaginella*? (MPPMT 2002)
(a) Heterophylly (b) Heterospory
(c) Homospory (d) Ligulate leaf

265. Club moss is grouped under: (Kerala PMT 2003)
(a) Algae (b) Fungi
(c) Bryophyta (d) Pteridophyta
(e) Gymnosperm

266. Jacket of the antheridia is compound of two ring cells in: (B.V. Pune 2003)
(a) *Pinus* (b) *Selaginella*
(c) Fern (d) Moss

267. Two distinct generations present in a single life history are common in: (PMET Punjab 2003)
(a) *Mangifera* (b) *Bacillus*
(c) *Dryopteris* (d) *Spirogyra*

ANSWERS

1—d	2—b	3—c	4—c	5—d	6—d	7—d	8—c	9—d	10—b	11—c	12—c
13—d	14—c	15—d	16—d	17—c	18—d	19—b	20—c	21—c	22—b	23—c	24—b
25—b	26—b	27—c	28—a	29—b	30—c	31—d	32—c	33—c	34—b	35—c	36—b
37—b	38—d	39—c	40—c	41—c	42—c	43—b	44—b	45—a	46—c	47—c	48—b
49—b	50—c	51—d	52—b	53—c	54—c	55—d	56—b	57—b	58—a	59—c	60—b
61—b	62—a	63—c	64—a	65—c	66—b	67—b	68—a	69—a	70—a	71—b	72—d
73—c	74—a	75—a	76—b	77—a	78—c	79—a	80—d	81—d	82—d	83—d	84—b
85—b	86—b	87—b	88—a	89—a	90—c	91—a	92—a	93—b	94—c	95—c	96—a
97—d	98—d	99—c	100—a	101—c	102—b	103—b	104—a	105—a	106—d	107—b	108—a
109—c	110—c	111—b	112—d	113—a	114—c	115—a	116—a	117—b	118—a	119—c	120—d
121—c	122—a	123—d	124—a	125—c	126—d	127—d	128—b	129—b	130—a	131—b	132—b
133—d	134—a	135—c	136—b	137—d	138—a	139—c	140—a	141—c	142—b	143—d	144—a
145—c	146—b	147—d	148—c	149—a	150—c	151—c	152—a	153—a	154—a	155—c	156—b
157—c	158—a	159—c	160—d	161—c	162—b	163—b	164—b	165—b	166—b	167—a	168—b
169—d	170—a	171—b	172—a	173—a	174—c	175—b	176—d	177—d	178—b	179—c	180—b
181—d	182—b	183—b	184—b	185—c	186—b	187—b	188—b	189—b	190—a	191—c	192—b
193—b	194—c	195—b	196—b	197—c	198—d	199—d	200—d	201—b	202—d	203—b	204—a
205—c	206—b	207—c	208—a	209—a	210—c	211—c	212—a	213—d	214—b	215—c	216—d
217—d	218—c	219—d	220—b	221—a	222—a	223—d	224—c	225—a	226—c	227—d	228—b
229—a	230—b	231—a	232—d	233—a	234—c	235—c	236—b	237—b	238—b	239—d	240—b
241—a	242—d	243—c	244—a	245—b	246—a	247—a	248—a	249—d	250—a	251—a	252—a
253—a	254—a	255—b	256—d	257—d	258—a	259—c	260—a	261—b	262—c	263—a	264—c
265—d	266—c	267—c									

EXPLANATION OF SELECTED QUESTIONS (*)

23. Pith or medulla is not present in the centre of protostele.

28. Megasporophyll in pteridophytes is associated with formation of megaspores and hence is comparable to carpel of angiosperms.

46. Dried plant again becomes green on absorbing moisture (*i.e.*, resurrects) in *Selaginella lepidophylla*.

70. In *Selaginella kraussiana*, suspensor is reduced and insignificant and there occurs elongation or enlargement of archegonial cavity, which forms a long embryo tube or embryoschlauch. The embryo lies at the tip of this tube and derives nutrition.

77. Prothallus in fern is produced by germination of haploid spore and hence haploid.

98. Pollen tube is absent in pteridophytes.

103. A homoeopathic medicine 'lycopodium' is extracted from a pteridophyte *Lycopodium* (club moss).

111. Heterospory is present in *Selaginella*, which is necessary for seed formation and hence it is of evolutionary significance.

136. Gametangia (the structures in which gametes are produced) *i.e.*, antheridia and archegonia are produced on prothallus of fern.

151. In dry condition, the outer thin-walls of annulus cells are drawn in due to loss of water from the cells.

176. Ovules or seeds are absent in pteridophytes.

197. The mucilaginous mass coming out of neck of archegonium of *Pteris* fern contains malic acid due to which antherozoids or sperms are attracted (chemotactic effect of malic acid).

224. The first seed plants (pteridosperms) or seed ferns appeared during the early carboniferous period of palaeozoic era.

230. Pyrenoids in chloroplast (algal character) in pteridophytes are present in mesophyll cells of *Selaginella*.

233. *Selaginella bryopteris* is commonly called Sanjeevani.

252. Rachis (petiole of compound leaf) of fern is covered with hairy ramenta.

253. Tree-like ferns were common in carboniferous period of late palaeozoic era and most of coal has been derived from these pteridophytes.

254. The 13-celled microspore or male gametophyte in *Selaginella* is shed from microsporangium, which is having 1 prothallial cell + 8 jacket cells + 4 androgonial cells (*i.e.*, 8 + 4 = 12 antheridial cells).

14

Gymnosperms

- General introduction
- Distribution and habitat
- General characters of Gymnosperms
- Classification of Gymnosperms
- Economic importance of Gymnosperms
- Life cycle of *Cycas*
- Life cycle of *Pinus*

The term Gymnosperm is derived from two Greek words: *Gymnos*, naked + *Sperma*, seed, *i.e.*, **naked seeded plants.**

Or

The ovules or seeds are not enclosed inside ovary or fruit wall.

- The term 'Gymnosperm' was first introduced by **Theophrastus.**
- Gymnosperms are the small group of plants, which constitutes a sub-division of **Spermatophyta** or **Phanerogams. Goebel** (1887) defined gymnosperms as **'Phanerogams without ovary'.**
- Gymnosperms are the **most primitive seed plants.** Age of higher gymnosperms is **mesozoic era.**
  (Although origin of order **Cycadofilicales** (seed ferns) of gymnosperms is in **late palaeozoic.**)
- Gymnosperms act as a **connecting link** (bridge) between pteridophytes and angiosperms.
- Gymnosperms are placed in:
  - (i) **Archegoniatae,** *i.e.*, having **archegonium** as female sex organ (bryophytes, pteridophytes, gymnosperms).
  - (ii) **Embryophyta:** **Embryo is formed** in life cycle (bryophytes, pteridophytes, gymnosperms and angiosperms).
  - (iii) **Tracheophyta,** *i.e.*, having vascular tissue or xylem and phloem (pteridophytes, gymnosperms and angiosperms).

Gymnosperms is a small group of plants having about **73 genera and 7,000 sps.**

In India, only **16 living genera with 153 sps.** are present.

DISTRIBUTION AND HABITAT

Gymnosperms are although **worldwide** in distribution, but these are more abundant in **temperate regions** as compared to tropical regions.

Some members **are grown in plains** as ornamental plants.

Few gymnosperms are **xerophytic,** *e.g.*, *Welwitschia* is a well known xerophytic gymnosperm. It grows mostly in South-West Africa, especially **'Sahara'** desert, *i.e.*, endemic to **South-West Africa.** It grows generally in such places, where **annual rainfall is below 1 inch.**

It is like a **'huge turnip'** with stem or axis mostly underground which is upto **1½ metre** in diameter and only **3 pairs of foliage leaves** at apex in whole life. Axis or stem tapers into **long roots.** Roots are extremely long and reach upto the water **level.**

(The length of the roots of *Welwitschia* has never been determined.)

- Generally, **gymnosperms** constitute dominant flora of **temperate regions.**

Habit

The plants are generally perennial, woody **trees** or **shrubs.** In general, **tallest trees** are in gymnosperms, *e.g., Sequoia sempervirens* is **366 ft** in height and *S. gigantea* is **342 ft** in height.

- The age is maximum in *S. gigantea* and it is considered that they live upto **4000–5000** years.

GENERAL CHARACTERS OF GYMNOSPERMS

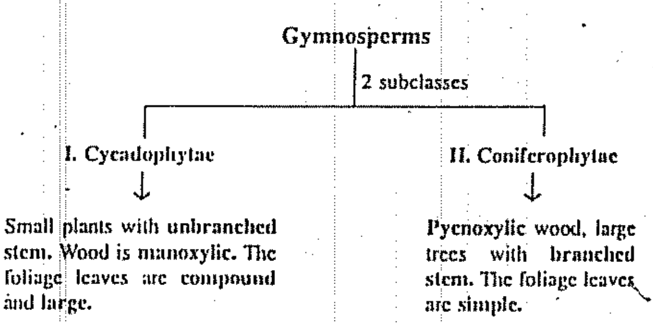
1. There is a **tap root system,** which may be anatomically **diarch to polyarch with exarch condition.**
2. The plants are generally perennial, woody large trees or shrubs. Stem is generally branched (unbranched in *Cycas).*
3. Leaves are scaly and foliage. The foliar leaves may be small or large.
4. The vascular bundles in stem are **conjoint, collateral, open. Secondary growth** is present and **annual rings** are formed.
5. The xylem consists of **xylem parenchyma** and **tracheids with bordered pits. Vessels** are **absent** in gymnosperms except order Gnetales *(Gnetum, Welwitschia* and *Ephedra).*
   - So Gnetales are **highest** gymnosperms and they act as **'connecting link'** between gymnosperms and angiosperms.

6. In phloem are present sieve cells and phloem parenchyma. Companion cells are altogether absent in phloem of gymnosperms.
7. The leaves are generally spirally arranged. They may be simple or compound with xerophytic characters (thick cuticle and sunken stomata).
8. The reproductive organs form cones or strobilus except **female organs of** *Cycas*.
9. The male cone or strobilus is made of overlapping **microsporophylls,** which bear **microsporangia** on their **abaxial** (lower surface).
10. Male gametophyte in gymnosperms has one or more **prothallial cells.**
11. Female cone or strobilus is formed by overlapping **megasporophylls,** which bear **ovules** (megasporangia), except *Cycas*, where there is no female cone.
12. Ovule in gymnosperms is generally **orthotropous (straight)** with a single integument (**unitegmic**) with 3 **layers,** *i.e.*, **outer fleshy, middle stony** and **inner fleshy.**
13. In the **nucellus** of ovule or megasporangium, there is a single **megaspore mother cell,** which undergoes R.D. to form 4 megaspores, out of which 3 degenerate and only one survives.
14. The single megaspore forms **female gametophyte** or endosperm.
    - o Endosperm in gymnosperms is formed **before fertilization** and is **always haploid.**
15. In the female gametophyte **at micropylar end,** two or more **archegonia** are produced.
16. Archegonium is with reduced neck (with **no neck canal cell).**
    - o Smallest archegonium of plant kingdom is present in gymnosperms.
17. Fertilization occurs by pollen tube (**siphonogamy**). Male gametes are ciliated in *Cycas* and *Ginkgo*. Double fertilization is absent in gymnosperms.
18. Pollination is **anemophilous** (by wind).
19. Development of oospore is **meroblastic,** *i.e.*, only lower half of zygote or oospore gives rise to **embryo proper. Suspensor formation** also occurs in gymnosperms.
20. **Polyembryony,** *i.e.*, development of more than one embryo is a **usual feature** of gymnosperms, but only one of them survives at later stages.
21. Wood is **manoxylic** (soft and loose), *e.g.*, *Cycas* or **pycnoxylic** (compact and hard), *e.g.*, *Pinus*.
22. Fruit formation is absent here and in the **embryo** of gymnosperms, 2 **or many cotyledons** are present, *e.g.*, 2 in *Cycas* and 10–11 in *Pinus*.
23. The seed in gymnosperms represents 3 generations:
    (a) **Parent sporophytic** generation is represented by **nucellus and integument.**
    (b) **Gametophytic** generation is represented by endosperm.
    (c) **Future sporophytic** generation is represented by embryo.

    So **gametophytic** generation is reduced here and dependent upon sporophytic generation.
24. There is a distinct alternation of generations.

CLASSIFICATION OF GYMNOSPERMS

A general classification of gymnosperms (by **Chamberlain,** 1934) is:



Small plants with unbranched stem. Wood is manoxylic. The foliage leaves are compound and large.

Pycnoxylic wood, large trees with branched stem. The foliage leaves are simple.

I. Cycadophytae

Divided into 3 orders:

1. **Cycadofilicales or Pteridospermales or Pteridosperms (Seed ferns)**
   These are fossils. They show some characters of ferns and some of **gymnosperms.** Their origin is in **late palaeozoic.**
   - o These are the **connecting link** between pteridophytes and gymnosperms, *e.g.*, *Medullosa* and *Lyginopteris*.
2. **Bennettitales or Cycadaeodales or fossil cycads**
   Their leaf bases are permanently attached to stem, *e.g.*, *Williamsonia* and *Williamsoniella*.
3. **Cycadales or Living cycads**
   They have typical **palm-like** appearance. Stem is unbranched, leaves large and male gametes are **ciliated,** wood is **manoxylic,** *e.g.*, *Cycas*, *Microcycas*, *Zamia*, *Stangeria*, etc.
   - o *Zamia pygmaea* is the **smallest** gymnosperm (25 cm in height).

II. Coniferophytae

Divided into 4 orders:

1. **Cordaitales**
   Fossils, *e.g.*, *Cordaites* and *Poroxylon*.
2. **Ginkgoales**
   Many fossils and a single **living genus,** *i.e.*, *Ginkgo biloba*, which is commonly known as **'Maiden Hair Tree'** (because of the resemblance of its leaves with those of 'Maiden Hair Fern' or *Adiantum*).
   It is also called **'Living fossil'** (because **single living** genus in a big fossilized order).
   - ● **Kaemfer** (1690) studied this maiden hair tree and named it as *Ginkgo*.
3. **Coniferales**
   It is the **largest order** of modern gymnosperms.

Here wood is pycnoxylic, stem branched, foliage leaves simple and reduced, called needles, *e.g.*, *Pinus* (pine), *Podocarpus*, *Thuja (Biota)*, *Sequoia* (red wood tree), *Araucaria* (Christmas tree or Monkey's puzzle), *Cupressus*, *Picea* (spruce), etc.

○ *Sequoia* is the largest gymnosperm (366 ft in height).

4. Gnetales

It is the highest order of gymnosperms and is a connecting link between gymnosperms and angiosperms.

This order is peculiar as it has 3 genera, which are quite different from each other.

e.g., *Gnetum*, *Ephedra* (Jointed fir) and *Welwitschia*. This is the only order in gymnosperms, where vessels are present in xylem.

ECONOMIC IMPORTANCE OF GYMNOSPERMS

Gymnosperms are economically very important. The members of this group are variously used by human beings as food, as medicines, as plants for decoration and in industries.

Economic importance of cycadophytae

1. Ornamental value

They look like palm tree and are evergreen in nature. Foliage leaves of some species, *i.e.*, *C. revoluta*, *C. circinalis*, *C. runphii* and *C. beddomei* are used for decoration purposes as they remain fresh for long period.

2. Food value

Different parts of the *Cycas* plants are used as food material.

(i) **Stem portion** of *C. revoluta* and *C. circinalis* is a good source of "Sago", a kind of starch used in making bread by poor people.

(ii) **Pith of the plant** *Encephlartos* is used in the preparation of **Kaffer bread.**

(iii) **Seeds and seed kernels** of some species of *Cycas* are roasted and taken as food.

(iv) **Leaves:** Young succulent leaves of some species of *Cycas* are cooked as vegetable.

(v) **Seeds and stem** of *Cycas revoluta* are used in making wine in Japan.

(vi) *Zamia* is rich in starch and is used as food by many Indians.

3. Medicinal value

Many useful medicines are prepared and extracted from the different parts of the *Cycas* plants.

(i) **Leaves:** The leaves of *C. circinalis* are medicinally very important. The fresh juice extracted from the leaves is used as medicine in stomach disorders, blood vomitting and other skin deseases.

(ii) **Seeds and megasporophylls:** Seeds and crushed bark of *Cycas* and its megasporophylls when mixed with coconut oil are used as **poultice** for sores and wounds in South India.

(iii) Pollen grains of some *Cycas* plants are reported to have some narcotic effect.

Economic importance of coniferophytae

1. Ornamental value

Almost all the members are of ornamental value. *Ginkgo biloba* is often named as **'Maiden Hair Tree'** because of its beautiful leaves. *Thuja*, *Araucaria*, *Abies*, *Cryptomeria*, *Pinus*, *Taxus* are grown in parks.

2. Edible value

(i) **Seeds:** Seeds of some species are edible, *e.g.*, *Pinus gerardiana* (chilgoza), *P. edulis*, *P. pinea*. Seeds of *Gnetum gnemon* are also edible. Seeds of *Ginkgo biloba* are nutritious.

(ii) **Shoots:** Shoots and inflorescence of *Gnetum* sps. are widely used as vegetables in many countries

3. Medicinal value

(i) *Gnetum ula* is a common source of edible oil. It is also used as massage in rheumatic pain. A volatile oil extracted from the shoots and leaves *of Biota (Thuja)* is used as vermifuge. Oil of *Juniperus* species is **medicinally important.**

(ii) **Leaves:** Leaves and seeds of *Taxus* are used as medicines.

(iii) A medicine of cancer called '*Taxol*' is obtained from the bark of *Taxus*.

(iv) An important **alkaloid 'ephedrine'** is obtained from *Ephedra*, used in treatment of **cough, cold** and other **respiratory disorders.**

4. Industrial use

(i) **Wood:** Some of the important conifers like spruce or *Picea* (maximum cellulose content) are an important source of **pulp wood** and are used in manufacture of paper. *P. markussii* is a valuable source of raw material. Timber is also obtained from various conifers. *Pinus* (chir), *Abies* (fir), *Cedrus* (cedar and deodar), *Sequoia* (red wood) are the chief source of various types of wood. The wood of *Juniperus* is used in making pencils, scales and holders. The wood of *Biota (Thuja)* is soft, brittle and durable.

(ii) **Tannins obtained from barks:**

(a) **The bark** of *Tsuga* sps. yields tannins used in making ink and drugs.

(b) **The bark** of *Larix europea* **yields a tannin Venice turpentine.**

(iii) **Resins:**

(a) **Manila Copal**, an important varnish resin is obtained from *Agathis* sps.

(b) **Fossil resin** (Amber) is obtained from extinct pine *Pinus succinifera*, used in jewellery and carved objects.

(c) **Turpentine** (Canada balsam), a well known turpentine, is obtained from *Abies balsamea* (used as mounting medium for biological preparations).

  - (d) *Pinus marittima* is a good source of Bordeus turpentine.
  - (e) Turpentine oil (used in paint industry) is obtained from a resin of *Pinus* species.
  - (f) Wood gas, wood tar and wood alcohol are obtained from various species of *Pinus, e.g., Pinus sylvestris.*
- (iv) Fibres: *Gnetum latifolium* yields fibre used in making ropes and nets.

CYCAS

Systematic position

Phylum — Tracheophyta
Class — Gymnospermae
Subclass — Cycadophytae
Order — Cycadales
Family — Cycadaceae
Genus — *Cycas*

Cycas is an **evergreen palm-like plant.** It is the only genus of family Cycadaceae represented in India. *Cycas* has approximately 20 species found in Australia, New Zealand, Japan, China, India, Burma (Myanmar) and Pacific Islands.

In India, four *Cycas* species are common in Orissa, Bengal, Assam, Tamilnadu, Karnataka and Andaman.

- (i) ***Cycas revoluta*:** It is a native of China and Japan and is locally called 'Tesso'. In our country, it is called **'Sago palm'.** Due to its primitive characters, it is also called **living fossil. It is upto 10 ft tall.**
- (ii) ***Cycas circinalis*:** Plants are about 12 to 15 ft tall and distributed upto 3500 ft. In Hindi, it is called as **Jangli-madan mast-ka-phul.**
- (iii) ***Cycas rumphii*:** Plants are about 12 ft tall. It is also cultivated in Indian gardens. In Tamil, it is called **Kama, Paiyindu.**
- (iv) *Cycas beddomei.*

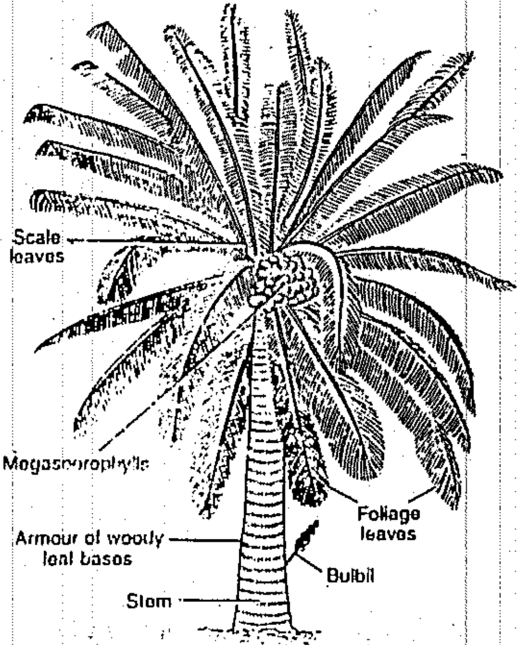


Fig. 14.1. External morphology of *Cycas*

External morphology

Cycas plant attains a height of 2–5 metres, although *C. media* (tallest) attains a height of 20 metres. Plant body is differentiated into **roots, stem and leaves.**

I. Roots

Roots arise from lower part of stem and are of two types:

- (i) **Normal roots:** These form a primary tap root system. **These roots are not green, positively geotropic with no root hairs.**
- (ii) **Coralloid roots:** From the lateral branches of the normal roots are formed **dichotomously branched, apogeotropic, bluish green** coralloid roots. ***Anabaena cycadaccarum, Nostoc*** and bacteria are found in their cortex and sometimes enter in these roots also. It is an example of symbiosis.

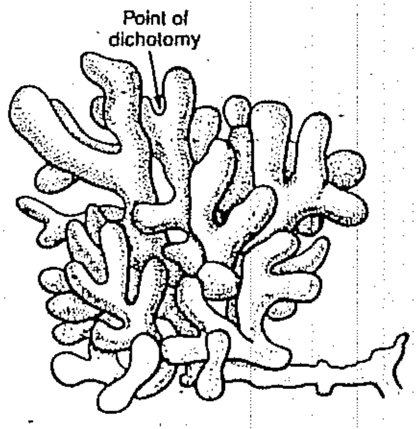


Fig. 14.2. Coralloid roots of *Cycas*

II. Stem

Stem is thick, cylindrical, columnar, small, aerial and unbranched. It is covered with persistant leaf bases and scale leaves, which are found in alternate whorls. There is a **crown** of foliage leaves at the apex of the plant.

III. Leaves

Leaves are **dimorphic,** ***i.e.,*** of two types:

- (i) **Scale leaves:** These are reduced form of foliage leaves without lamella and are arranged in a compact spiral and alternate manner. A single scale leaf is a brown, dry, woody, triangular structure, covered with brown hairs or **ramenta.**
- (ii) **Foliage leaves:** These are green unpinnately compound present on the apex of the plant forming a crown. These leaves are upto 3 metres in *C. circinalis.* Leaves are leathery and thick, some leaflets at the base of the rachis are reduced to spines.

- The vernation or ptyxis is **circinate** (*i.e.*, coiled in young stage).

Anatomy

I. Stem

It resembles a **dicotyledonous stem** having the following tissues:

(a) **Epidermis:** It is the outermost layer ruptured due to persistent leaf bases. It is made up of compactly arranged thick-walled cells.

(b) **Cortex:** Cortex is large, thin-walled, parenchymatous, having a number of mucilage canals. Starch grains are found in the cortex.

(c) **Endodermis and pericycle:** These layers are not very clear.

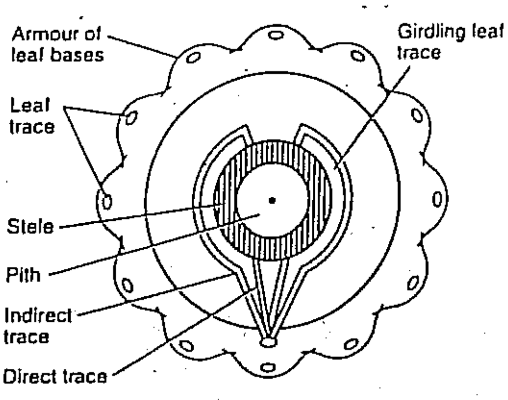


Fig. 14.3. T.S. stem of *Cycas* showing girdling and direct leaf traces

(d) **Stele:** Vascular cylinder is very small having numerous small closely arranged vascular bundles, which are **conjoint, collateral** and **open.** Xylem is **endarch** and consists of tracheids, which have spiral thickening in protoxylem and scalariform thickenings in metaxylem. Phloem is devoid of companion cells. **Albuminous** cells are found in phloem.

(e) **Leaf traces:** There are several leaf traces present in the cortex. Four vascular bundles enter the base of leaf, two of these are **direct** and other two arise from the stele of opposite side and after making **semicircle,** they enter the leaf. These indirect leaf traces are known as **girdling leaf traces** or **leaf girdles.**

(f) **Pith:** It is large, parenchymatous and is having a number of **mucilage canals. Starch grains** are also found in pith.

Secondary growth: At first a complete ring of cambium is formed by the development of interfascicular cambium, forms secondary xylem and secondary phloem. This ring is **short lived** and secondary cambium is formed from pericycle, which produces secondary xylem towards inner side and secondary phloem towards outer side. After some time this ring also becomes non-functional and another cambium ring is formed from cortex and again cutting off secondary xylem and secondary phloem. In this way successive zones of secondary xylem and phloem alternating with parenchymatous tissues are formed. In *C. pectinata*, **14 rings** have been reported and this condition is called **polyxylic** or **polycyclic condition.** Secondary xylem shows characteristic **multiseriate bordered pits.** Large amount of parenchymatous cells are present with secondary xylem tracheids, so the wood is called **soft wood** or **manoxylic** wood.

II. Leaf

(a) **Rachis:** T.S. of rachis shows the following structures:

(i) **Epidermis:** The outermost layer is epidermis with thick cuticle having stomata.

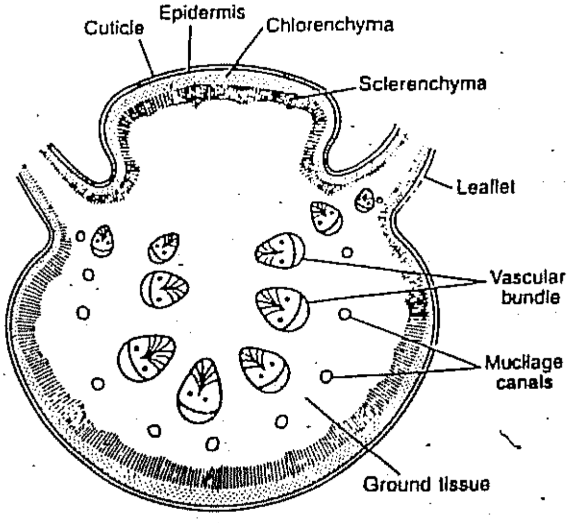


Fig. 14.4. T.S. rachis of *Cycas*

(ii) **Hypodermis:** Epidermis is followed by a well developed hypodermis, differentiated into **outer chlorenchymatous** and **inner sclerenchymatous** regions.

(iii) **Ground tissue:** Below the hypodermis is well developed parenchymatous ground tissue with mucilage canals. The vascular bundles are arranged forming an **inverted omega** (Ω). Each vascular bundle is surrounded by a sclerenchymatous sheath and is **conjoint, collateral** and **open.** In most parts of the **rachis,** xylem is **mesarch,** *i.e.*, centripetal xylem **towards periphery** and two patches of centrifugal xylem one on each side of protoxylem of centripetal xylem. Outside the centrifugal xylem is cambium and then phloem towards periphery.

(b) **Leaflet:** The margins of leaflet in case of *C. revoluta* are curved downwards and inwards but in *C. circinalis*, the margins are flat. The following tissues can be differentiated in the T.S. of leaflet:

(i) **Epidermis:** Epidermis is single layered with thick cuticle. The upper epidermis is complete whereas the lower epidermis is interrupted by several stomata present only in the region of blade (**hypostomatic**). Upper and lower epidermis are covered by layer of thick cuticle.

(ii) **Hypodermis:** Just below the upper epidermis, there are several layers of sclerenchymatous hypodermis while above the lower epidermis it is present only in the midrib portion.

(iii) **Mesophyll:** Mesophyll is differentiated into **palisade parenchyma** on upper side and **spongy parenchyma** on lower side. Palisade tissue is made-up of vertically elongated cells without intercellular spaces. Both tissues contain chloroplasts.

(iv) **Vascular bundle:** In the midrib there is a large vascular bundle. The vascular bundle is **collateral and closed.** The xylem is **mesarch,** *i.e.*, **diploxylic condition** with centripetal and centrifugal xylem.

(v) **Transfusion tissue:** On each side of the midrib in between the palisade and spongy tissues is present **transfusion tissue** made-up of horizontally arranged tracheids which supply water and mineral to mesophyll tissue upto margins.

III. Root

Root of *Cycas* resembles dicotyledonous root. T.S. of normal root reveals the following structures:

(i) **Epiblema:** This is the outermost layer with root hairs.

(ii) **Cortex:** Just below the epiblema is multilayered parenchymatous cortex. Some **tannin cells** are present in the cortex.

(iii) **Endodermis:** Below the cortex is present endodermis which is made up of barrel-shaped cells and below it is a layer of pericycle.

(iv) **Vascular tissues:** It consists of xylem and phloem which are radially arranged, *i.e.*, on different radii.

(v) **Pith:** It is generally absent.

Secondary growth: It is like dicotyledonous plants.

Coralloid roots

Structure of stele is similar to normal roots but cortex is divided into 3 zones:

1. **Outer cortex:** Having several layers of parenchymatous cells.
2. **Middle cortex (algal zone):** Filled with blue-green algae, *Anabaena* and *Nostoc*.
3. **Inner cortex:** Having several layers of parenchymatous cells. Roots are **diarch, triarch** and sometimes **polyarch.**

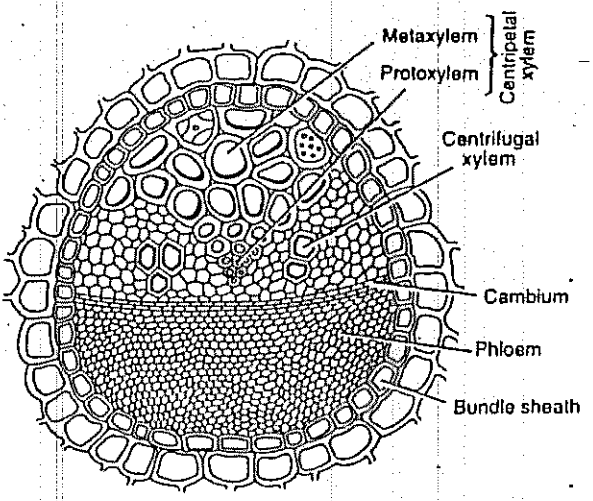

Metaxylem
Protoxylem
Centripetal xylem
Centrifugal xylem
Cambium
Phloem
Bundle sheath

Fig. 14.5. Single vascular bundle of rachis of *Cycas*

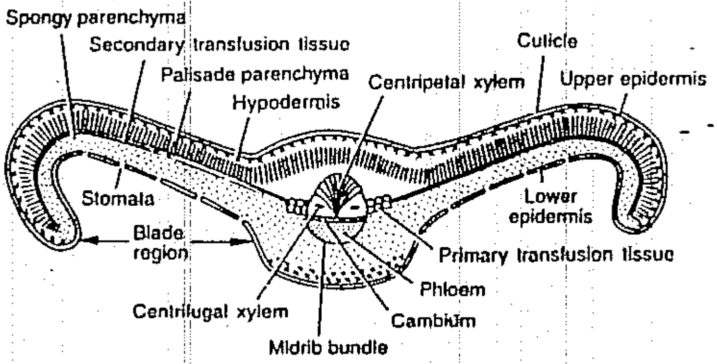

Spongy parenchyma
Secondary transfusion tissue
Palisade parenchyma
Hypodermis
Centripetal xylem
Cuticle
Upper epidermis
Stomata
Blade region
Lower epidermis
Primary transfusion tissue
Phloem
Centrifugal xylem
Cambium
Midrib bundle

Fig. 14.6. T.S. leaflet of *Cycas* (diagrammatic)

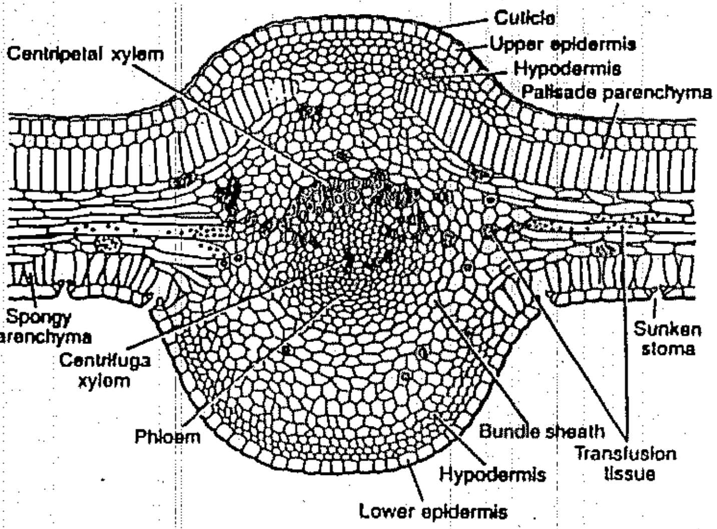

Cuticle
Upper epidermis
Hypodermis
Palisade parenchyma
Centripetal xylem
Spongy parenchyma
Centrifuga xylem
Phloem
Sunken stoma
Bundle sheath
Transfusion tissue
Hypodermis
Lower epidermis

Fig. 14.7. T.S leaflet of *Cycas* (a portion enlarged)

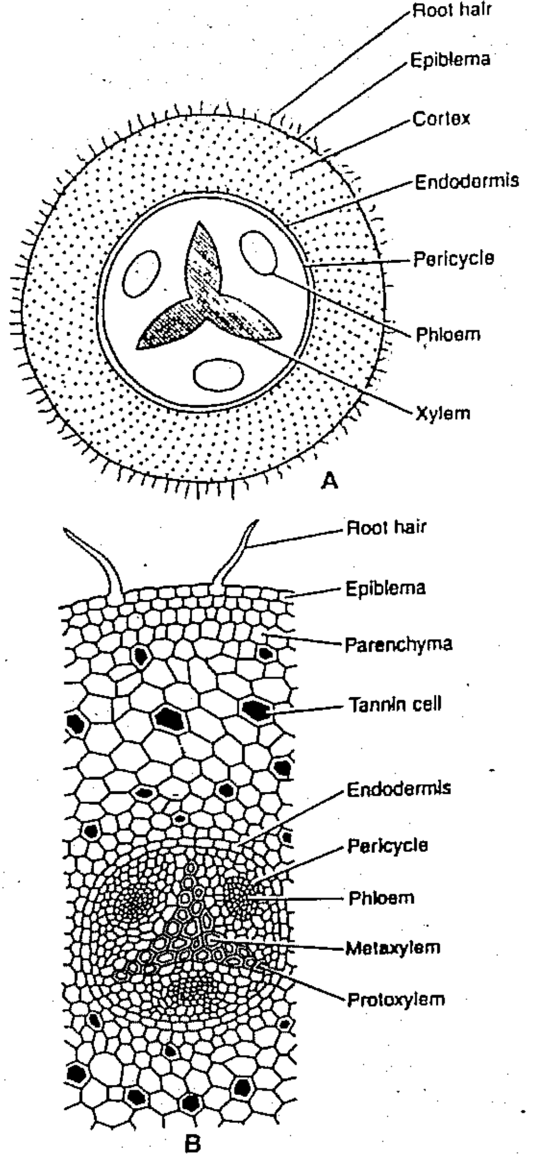

Root hair
Epiblema
Cortex
Endodermis
Pericycle
Phloem
Xylem
A
Root hair
Epiblema
Parenchyma
Tannin cell
Endodermis
Pericycle
Phloem
Metaxylem
Protoxylem
B

Fig. 14.8. T.S. normal root of *Cycas:* A. Diagrammatic B. A part cellular

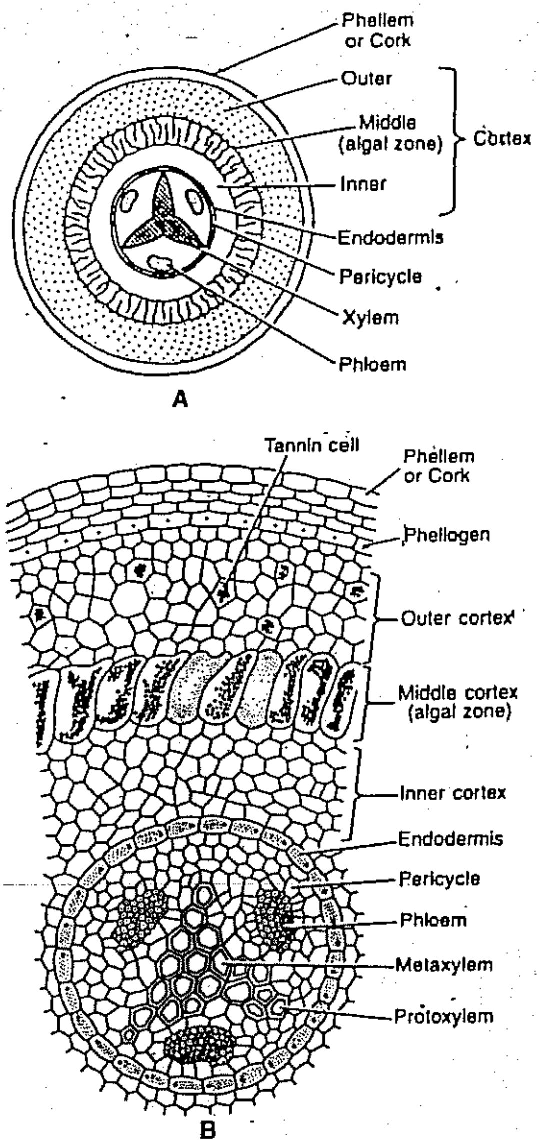

Phellem
or Cork
Outer
Middle
(algal zone)
Inner
Cortex
Endodermis
Pericycle
Xylem
Phloem
A
Tannin cell
Phellem
or Cork
Phellogen
Outer cortex
Middle cortex
(algal zone)
Inner cortex
Endodermis
Pericycle
Phloem
Metaxylem
Protoxylem
B

Fig. 14.9. T.S. Coralloid root of *Cycas:* A. Diagrammatic B. A part cellular

Reproduction

The *Cycas* plants are strictly dioecious and reproduce by the following methods:

(1) Vegetative reproduction

Takes place with the help of bulbils which are produced on the stem in the axil of scale leaves. They get detached from the parent plant and germinate to give rise to the new plants.

(2) Sexual reproduction

Plant of *Cycas* is sporophyte (2*n*) and the sexual reproduction is of oogamous type, *i.e.*, takes place by the fusion of distinct male and female gametes. The male and female gametes are formed by the germination of micro and megaspores which are born on microsporophylls and megasporophylls. The microsporophylls are grouped together to form a compact conical structure called male cone, whereas the megasporophylls are not aggregated to form a cone, they are produced at the apex of the stem in succession with the leaves.

Male reproductive organ

Male cone: In *Cycas*, the male cone is produced every year singly at the apex of the stem. The cone being terminal, the apical growth of stem is stopped for some time. The cone is

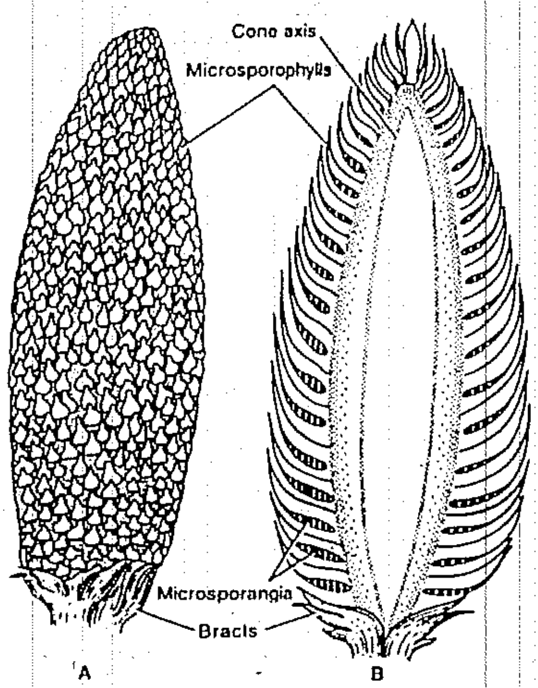


Fig. 14.10. *Cycas:* A. External view of male cone B. L.S. of male cone

later pushed to lateral side and the stem continues to grow (**Sympodial growth**).

Male cone is an ovoid or conical structure and is on the average 20 cm long (longest is 45 cm long). In *C. circinalis*, it is about 25 cm long. It consists of a number of microsporophylls arranged spirally in acropetal succession on a central axis.

Microsporophyll: It is a flattened structure, narrow below and broader above. The upper portion is expanded in the form of a sterile disc called apophysis. The dorsal side of microsporophyll is smooth and sterile whereas on the ventral side are present a large number of microsporangia. The number of microsporangia on a single microsporophyll are 900-1000. In *C. media*, there are about 1160 sporangia.

Microsporangium: Each microsporangium is a globular, sac-like structure having a large number of microspores.

Microspore: Each microspore has an outer wall called exine which is thin at one end and thick at other places. The inner wall is intine which is thin.

Sori: The sporangia are arranged in groups of 3 or 4 to form sori. These sori are separated into two groups by a median sterile line. Generally there are about **500–700** sori on each sporophyll.

Development of male gametophyte (before pollination)

Microspore is the beginning of the male gametophytic generation and its germination starts while the microspores are still enclosed in the microsporangium.

Initially a small vegetative cell or **prothallial cell** is cut off at one end, leaving a large antheridial cell. The **antheridial cell** again divides into a small generative cell and a large tube cell. **The microspore is shed at this 3-celled stage.**

Female reproductive organs

The female reproductive structures are megasporophylls arising spirally in acropetal succession, arranged loosely on the stem apex of female plant.

Each megasporophyll is regarded as a modified foliage leaf and is about 5–10 inches long. The apical part is leafy, sterile, pinnately divided and below it is a fertile stalk having **2–4 pairs of ovules.** The ovules and sporophylls are covered by yellow wooly hairs which get lost when the ovules become large. The **ripe seeds have orange red colour.**

In the genus *Cycas*, there is great variation regarding the pinnate character of megasporophyll and the number of ovules per sporophyll. In *C. revoluta* and *C. pectinata*, the lamina is large with well developed pinna and the ovules are 4 to 6 in number.

In *C. circinalis* and *C. rumphii*, the lamina is somewhat reduced but the pinna are greatly reduced. In *C. normanbyana*, both are greatly reduced and the ovules are also two in number.

Megasporangium (ovule): The ovules of *Cycas* are largest in nature, can be seen by naked eyes. In *C. circinalis*, the ovules **are largest in size, *i.e.*, about 6 cm in length and 4 cm in diameter.**

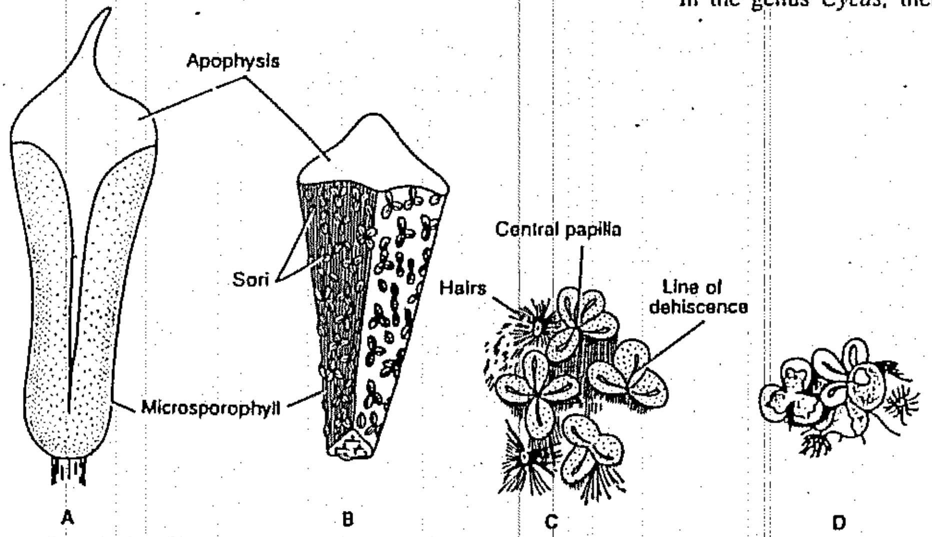


Fig. 14.11. *Cycas:* A. Dorsal view of microsporophyll B. Ventral view of microsporophyll C. Microsporangia in sori (undehisced) D. Dehisced microsporangia.

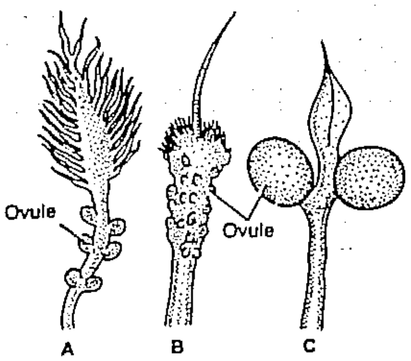

Ovule
Ovule
A
B
C

Fig. 14.12. A–C. Megasporophylls of different species of *Cycas*

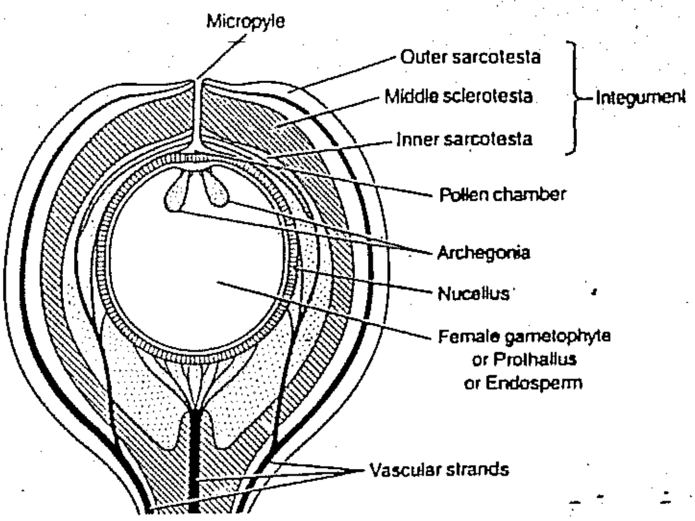

Micropyle
Outer sarcotesta
Middle sclerotesta
Inner sarcotesta
Integument
Pollen chamber
Archegonia
Nucellus
Female gametophyte or Prothallus or Endosperm
Vascular strands

Fig. 14.13. L.S. megasporangium (ovule) of *Cycas*

The ovules are **orthotropous and unitegmic.** The main body of the ovule is nucellus, covered by a single thick integument except at the top where a small opening is left called **micropyle.**

The integument is differentiated into 3 layers:

1. Outer fleshy layer of red colour
2. Middle stony layer
3. Inner fleshy layer (absorbed later on by the developing female gametophyte). The apex of the nucellus develops a beak-like process, the **nucellar beak,** which projects into the **micropyle.**

Development of female gametophyte (endosperm)

The megaspore is the beginning of female gametophytic generation. A spore mother cell is differentiated in the nucellus. It divides twice to form a linear tetrad of megaspores, out of which three of the micropylar end degenerate. The lowermost megaspore is the first cell of female gametophyte. It enlarges considerably by absorbing some of the nucellus cells. The megaspore nucleus divides repeatedly by free nuclear division and a vacuole appears in the centre and many free nuclei are embedded in the surrounding cytoplasm. Later a parietal tissue is formed by centripetal wall formation, leading to the formation of **prothallus** or **female gametophyte** or **endosperm,** which provides food for the developing embryo.

Development and structure of archegonium: Each archegonium develops from a single superficial cell of the endosperm near the micropyle. Usually **3–6 archegonia** develop on one gametophyte.

Each archegonium is having **2 neck cells, a ventral canal nucleus** and **an egg.** The ventral canal nucleus is ephemeral structure and disorganizes soon. **Neck canal cells are absent.** The group of archegonia are situated at the bottom of the depression called **archegonial chamber,** in which the nucellus degenerates forming a liquid.

- o The egg of *Cycas* is largest in the plant kingdom.

Pollination

The pollen grains of *Cycas* are light in weight and easily blown away by wind at 3-celled stage (prothallial cell, generative cell, tube cell). At the time of pollination, a large **pollination drop** comes out of micropylar end of ovule by **disorganization of nucellar beak.** The pollen grains are entangled on this drop and as it dries, the pollens are drawn into the pollination chamber.

Development of male gametophyte (After pollination)

The pollen grains in pollination chamber absorb water and begin to germinate. The tube cell elongates, pierces the exine and forms a pollen tube. The pollen tube is slightly swollen and branched at tip. The pollen tube acts as **haustorium absorbing** food from nucellus.

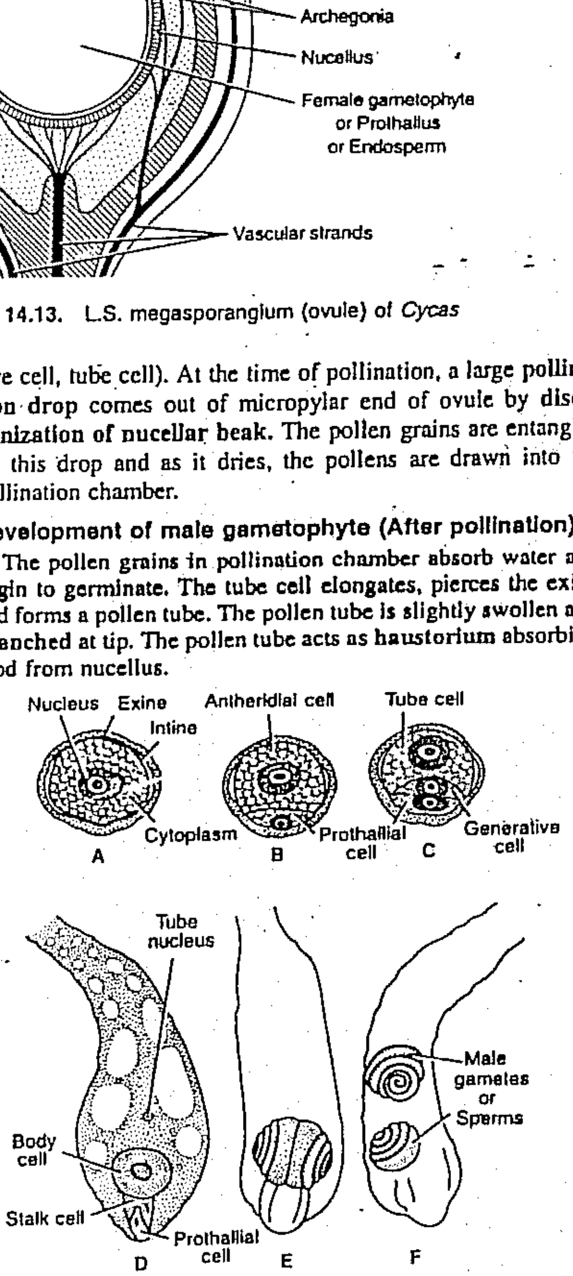

Nucleus
Exine
Intine
Cytoplasm
A
Antheridial cell
Prothallial cell
B
Tube cell
Generative cell
C
Tube nucleus
Body cell
Stalk cell
Prothallial cell
D
E
Male gametes or Sperms
F

Fig. 14.14. A–F. Development of male gametophyte in *Cycas*

The generative cell divides into two: (i) the stalk cell and (ii) body cell. Body cell enlarges and forms several **blepharoplasts**, which later form cilia. It divides into two daughter cells and each daughter cell metamorphoses into one antherozoid or sperm or male gamete.

- o **The male gametes of *Cycas* are largest** (300 µ) in nature, visible to naked eye and are **oval in form, broad (top-shaped)** and naked at posterior end and spirally coiled in the anterior half with thousands of small cilia. The sperms pass into pollen tube and reach the tip of the tube.

Microspore < Prothallial cell / Antheridial cell < Tube cell / Generative cell <
Stalk cell < Sperm
Body cell < Sperm

Fertilization

The pollen tube containing tube nucleus and two sperms becomes turgid and bursts discharging the contents into archegonial chamber. Only a single sperm enters in each archegonium through neck. The male nucleus of the sperm fuses with the egg nucleus to form a **zygote or oospore** ($2n$).

Thus the fertilization brings to an end of the gametophytic generation and the zygote is the initial stage of sporophytic generation.

Embryology

The **oospore** is the beginning of sporophytic generation. Its single nucleus divides repeatedly by free nuclear divisions. A vacuole appears in the centre and pushes nuclei and cytoplasm towards periphery. Centripetal wall formation takes place from periphery to centre in the lower end forming a small mass of cells called **embryonal mass**. This mass soon becomes differentiated into 3 zones:

(1) Haustorial layer (2) Suspensor layer (3) Proembryo.

- **Proembryo** forms almost all parts of embryo.

Suspensor layer elongates and forms a spirally coiled suspensor which pushes the embryo into endosperm.

Proembryo forms **plumule** and **two cotyledons**. Tip of the suspensor forms **radicle**.

Several developing embryos may be found in one young seed (**polyembryony**) due to presence of many archegonia, but only one remains at maturity.

Seed formation

After fertilization, the ovule is converted into a seed. A seed has the following parts:

1. Seed coat or Testa: It is formed by outer fleshy layer and the middle stony layer.

2. Micropyle: It is present in the form of a small opening at the top of the seed.

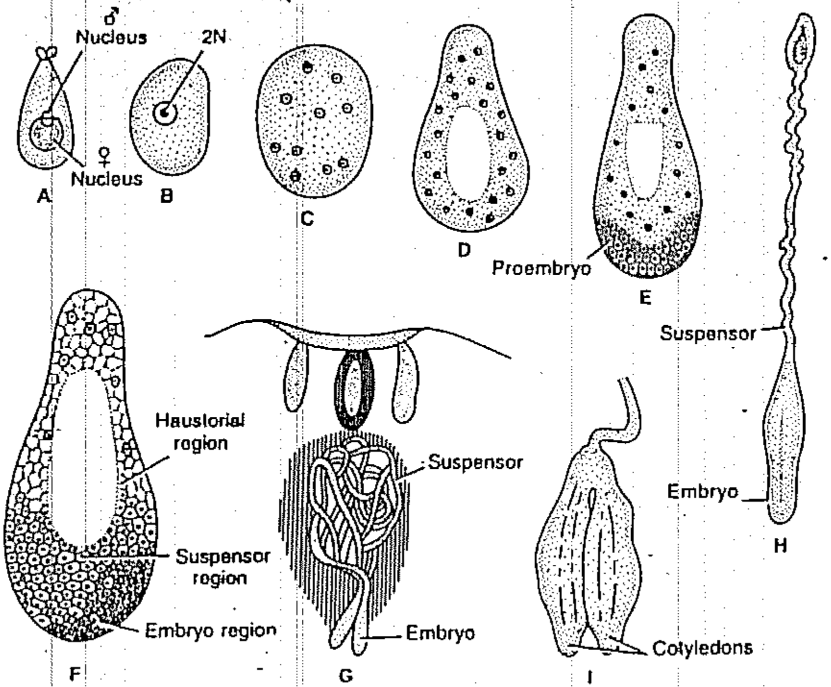

♂ Nucleus
2N
♀ Nucleus
A
B
C
D
Proembryo
E
Suspensor
Haustorial region
Suspensor region
Embryo region
F
Suspensor
Embryo
G
Cotyledons
I
Embryo
H

Fig. 14.15. Development of zygote and embryo in *Cycas*

3. Endosperm: Inner to the seed coat is well developed tissue called **endosperm** containing food.

Embryo

In the endosperm lies a well developed embryo having the following structures: (a) **Two cotyledons** (b) **A plumule** (c) **A radicle**.

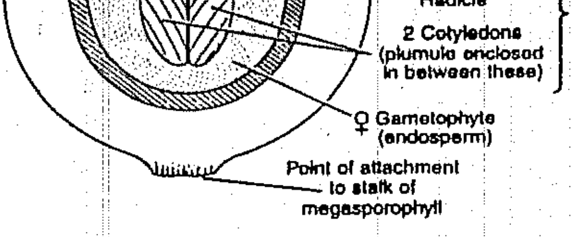

Outer fleshy layer
Middle stony layer
Seed coat
Remains of nucellus as a plug (on micropylar end)
Disintegrating suspensor
Coleorhiza
Radicle
2 Cotyledons (plumule enclosed in between these)
Embryo
♀ Gametophyte (endosperm)
Point of attachment to stalk of megasporophyll

Fig. 14.16. L.S. of seed of *Cycas*

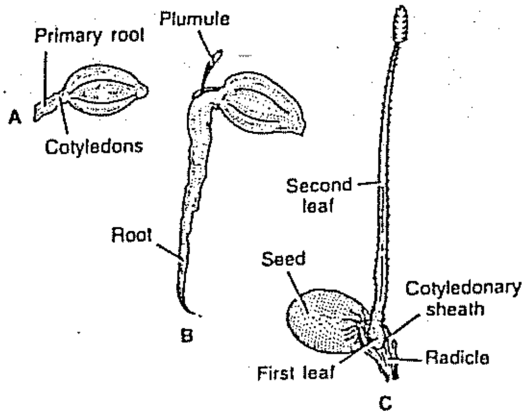

Primary root
Plumule
A
Cotyledons
Root
B
Second leaf
Seed
Cotyledonary sheath
Radicle
First leaf
C

Fig. 14.17. A–C. Germination of seed of *Cycas*

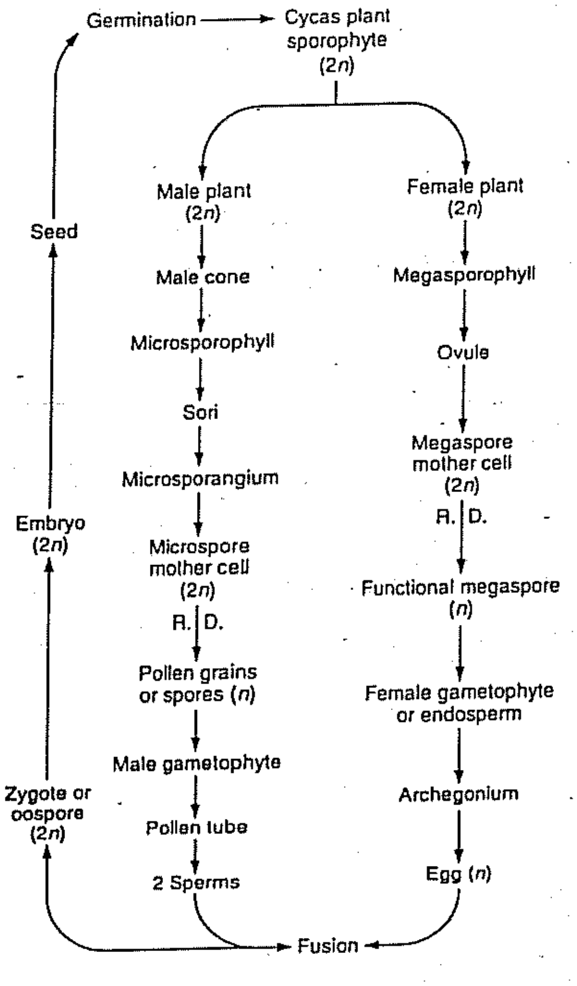

Germination
Cycas plant sporophyte (2n)
Male plant (2n)
Female plant (2n)
Seed
Male cone
Megasporophyll
Microsporophyll
Ovule
Sori
Megaspore mother cell (2n)
Microsporangium
R. D.
Embryo (2n)
Microspore mother cell (2n)
Functional megaspore (n)
R. D.
Pollen grains or spores (n)
Female gametophyte or endosperm
Male gametophyte
Zygote or oospore (2n)
Archegonium
Pollen tube
2 Sperms
Egg (n)
Fusion

Fig. 14.18. Graphical representation of life cycle of *Cycas*

Germination of seed

There is hypogeal germination of *Cycas* seed. In germination, the radicle forms a tap root. The cotyledons remain in the endosperm under the surface of soil. The plumule grows up and forms some scale leaves and later foliage leaves.

- *Cycas* seed represents 3 generations:
  - (i) **Old sporophytic generation:** Represented by seed coat and nucellus.
  - (ii) **Female gametophytic generation:** Represented by endosperm.
  - (iii) **Future sporophytic generation:** Represented by embryo.

PINUS

Systematic position

Phylum — Tracheophyta
Class — Gymnospermae
Subclass — Coniferophytae
Order — Coniferales
Family — Pinaceae
Genus — *Pinus*

Occurrence and distribution

It is commonly known as **'pine'** with about 90 species among which six species are found in India (N. East and N. West Himalayas) occurring in wild state. These are:

(1) *Pinus gerardiana* or **Chilgoza pine.**
(2) *Pinus wallichiana* (or *P. excelsa*) or **Blue pine or Kail:** Grow upto 3500 metres above sea level.
(3) *P. roxburghii* (or *P. longifolia*) or **Chir pine.**
(4) *P. merkusii* or **Teenasserim pine:** Grow upto 600 metres above sea level only.
(5) *P. insularis* (or *P. khasya*) or **Khasi pine.**
(6) *P. armandi* or **Armand's pine.**

In addition to these, 4 sps. of **exotic** pines, *i.e., P. montana, P. laricia* and *P. sylvestris* (**Scotch pine**) and *P. strobus* (**white pine**) have been introduced in India.

External morphology

Pinus is an evergreen, perennial plant of xerophytic nature. Mostly the species are tall and straight. The whorled branching gives a typical **conical** or **excurrent appearance** to the plant (due to apical dominance). The plant body is **sporophyte** and the plants are **monoecious.**

The plant body is differentiated into roots, stem and leaves.

Root

There is a prominent tap root system which is shallow. Lateral roots developing later on help in anchoring the plant in the soil. The root hairs are **poorly developed** and hence **ectotrophic mycorrhiza** (symbiotic association of fungal hyphae with the branches of roots) is of common occurrence in *Pinus* for absorption of water.

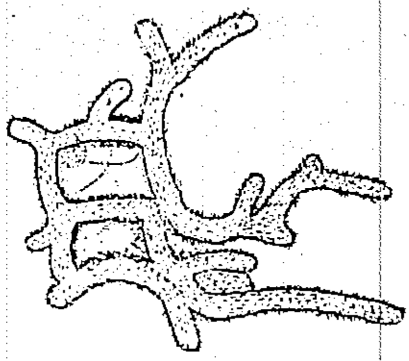


Fig. 14.19. Mycorrhizal root of *Pinus* (a portion)

Stem

The stem is tall, erect, cylindrical and the branching is monopodial type. The main stem is covered by scaly bark. Branches are developed from the buds present in the axil of scale leaves and appear to be in whorls. These branches develop every year and help in calculating the age of the plant.

Branches are of two types:

(i) **Long shoots or branches of unlimited growth:** These have apical buds, grow indefinitely in whorls each year from the buds in the axil of scale leaves. These shoots spread out horizontally and bear scale leaves on them.

(ii) **Dwarf shoots or branches of limited growth:** These branches lack apical buds and grow for a definite or short period. They arise in the axil of scale leaves on long shoots.

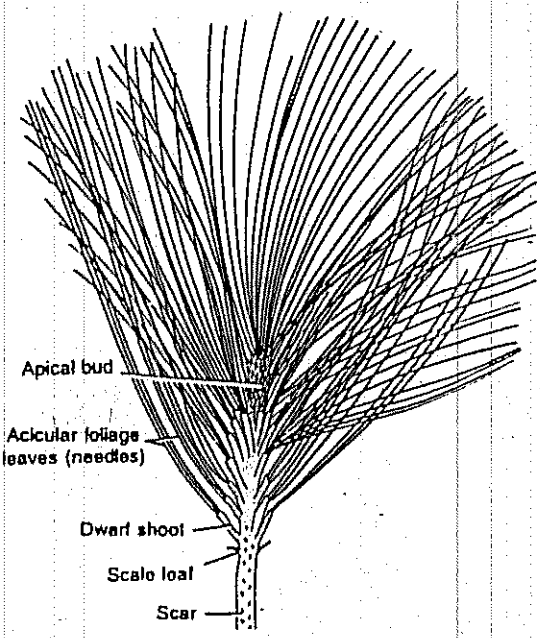


Fig. 14.20. A long shoot with dwarf shoots (spurs) of *Pinus roxburghii*

Leaves

Leaves are also of two types:

(i) **Scale leaves:** These are present on both long as well as dwarf shoots. They are small, thin, flattened and brown structures and fall off with maturity of these branches.

(ii) **Foliage leaves:** These are present only at the apex of dwarf shoots. They are long, needle-like green structures, present for 3 or more years and thus the plants are evergreen. Their size and number is different in different species.

The dwarf shoot with needles is called a 'spur'. On the basis of number of needles, spur is of different types as:

(i) **Monofoliar** (with one needle), *e.g., P. monophylla.*

(ii) **Bifoliar** (with two needles), *e.g., P. merkusi* and *P. sylvestris.*

(iii) **Trifoliar** (with three needles), *e.g., P. gerardiana* and *P. roxburghii.*

(iv) **Pentafoliar** (with five needles), *e.g., P. wallichiana.*

Anatomy

I. Anatomy of root

The internal structure of root is **identical with the dicot root.** A T.S. of root reveals the following structures:

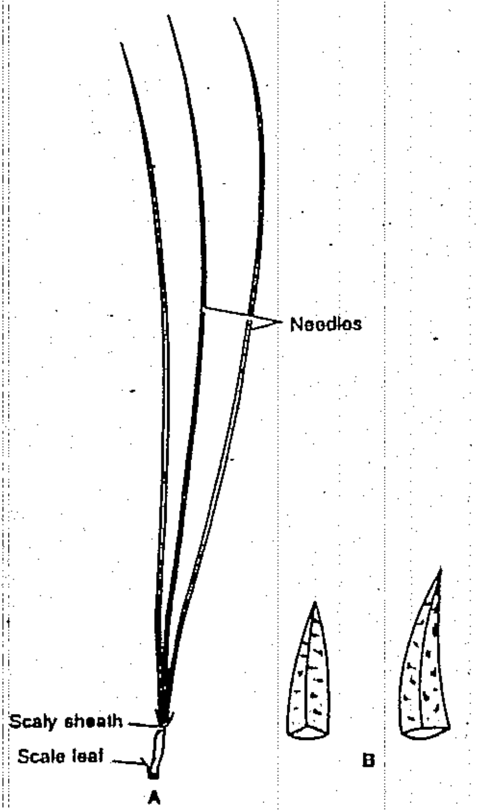


Fig. 14.21. *Pinus roxburghii.* **A.** Trifoliar spur **B.** Triangular outline of needle

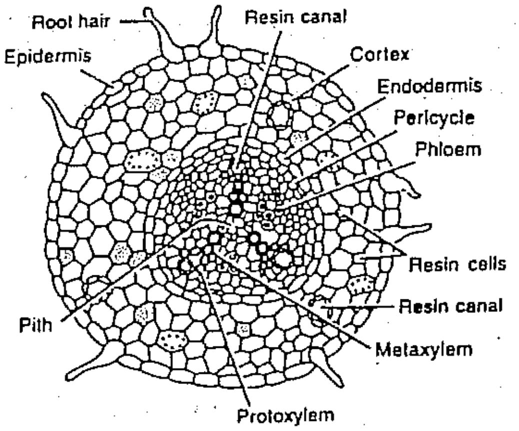

Root hair
Resin canal
Epidermis
Cortex
Endodermis
Pericycle
Phloem
Resin cells
Resin canal
Pith
Metaxylem
Protoxylem

Fig. 14.22. T.S. of young root of *Pinus*

1. **Epiblema:** Outermost limiting layer and is single layered thick. From this piliferous layer, thin-walled unicellular root hairs arise.

2. **Cortex:** A wide zone having 4–5 layers of parenchymatous cells.

3. **Endodermis:** A single layer of suberized cells.

4. **Pericycle:** Endodermis is followed by **multilayered** pericycle.

5. **Vascular tissues:** Radial vascular bundles are present.
   (i) **Xylem:** **Exarch condition with bifurcated** (Y-shaped) protoxylem. Resin canal is present between two arms. **Xylem is devoid of vessels.**
   (ii) **Phloem:** Alternating with the xylem groups are present phloem patches. **Companion cells are absent.**

6. **Pith:** Pith is generally absent. If present, it is very small and made-up of parenchymatous cells.

Secondary growth: In young roots, cambium is absent but at maturity below the phloem patches, arches of cambium are formed. It cuts off secondary xylem on the inner side and secondary phloem on the outer side.

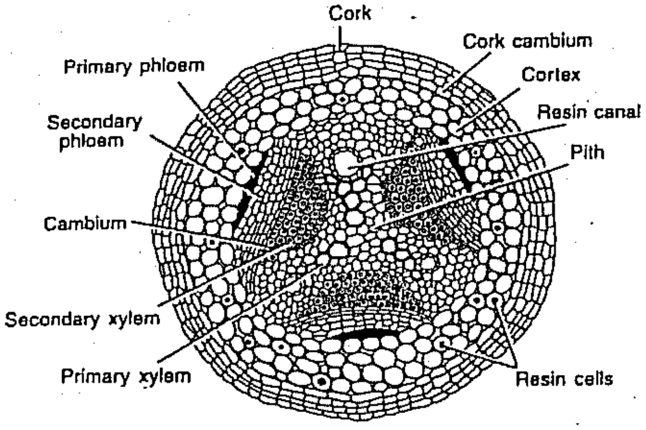

Cork
Cork cambium
Primary phloem
Cortex
Secondary phloem
Resin canal
Pith
Cambium
Secondary xylem
Primary xylem
Resin cells

Fig. 14.23. T.S. of old root of *Pinus* showing secondary growth

The cells of the outermost layer of pericycle form **cork cambium** (phellogen), which cuts off **phellem** (cork) on the outer side and **phelloderm** (secondary cortex) on the inner side. Finally epiblema ruptures and the cork layer is exposed.

II. Anatomy of the stem

T.S. of stem reveals the following structures:

1. **Epidermis:** It is the outermost layer made up of small compactly arranged cells (heavily cuticularised).

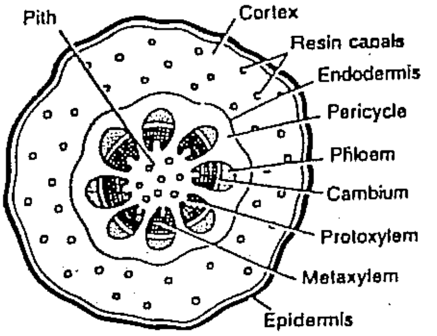

Pith
Cortex
Resin canals
Endodermis
Pericycle
Phloem
Cambium
Protoxylem
Metaxylem
Epidermis

Fig. 14.24. T.S. of young stem of *Pinus*

2. **Hypodermis:** Below epidermis are 4–5 layers of sclerenchymatous cells constituting **hypodermis.**

3. **Cortex:** Inner to the hypodermis is a wide zone of cortex, some cells are filled with **tannin.**

4. **Endodermis:** It is the innermost layer of the cortex, made-up of single layer of cells.

5. **Vascular cylinder (Stele):** It is of eustelic type having a ring of 5–8 closely arranged vascular bundles. Vascular bundles are **conjoint, collateral and open.**

Xylem: Xylem is endarch, consists of only tracheidal cells, vessels are absent. Therefore wood is known as **non-porous.**

Protoxylem consists of annular and spiral tracheids. Metaxylem tracheids have **uniseriate bordered pits** on their radial walls. These are also having **bars of sanio.**

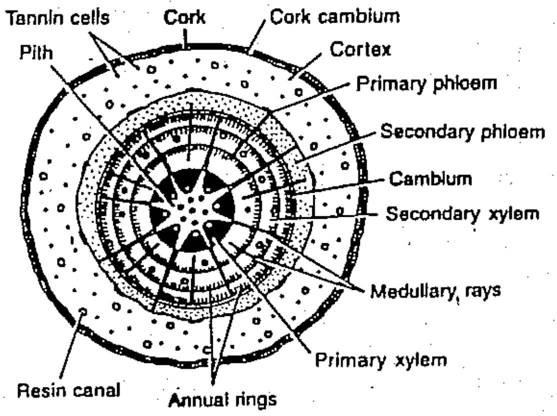

Tannin cells
Cork
Cork cambium
Pith
Cortex
Primary phloem
Secondary phloem
Cambium
Secondary xylem
Medullary rays
Primary xylem
Resin canal
Annual rings

Fig. 14.25. T.S. of old stem of *Pinus* showing secondary growth

Phloem: It is situated on the outer side of vascular bundle and is made-up of phloem parenchyma and sieve cells. Companion cells are lacking.

Cambium: In between the xylem and phloem of each vascular bundle, there is a strip of intrafascicular cambium.

6. **Medullary ray:** In between the vascular bundles is a zone of parenchymatous cells connecting the pith and the cortex.

7. **Pith:** In the centre of the stem is a zone of thin-walled parenchymatous cells known as pith.

Resin canals: Each resin canal is having 2 outer layers of sclerotic (sclerenchymatous) cells and an inner layer of glandular secretory epithelial cells which secrete **resinous** substances like turpentine.

- Resin canals are present in cortex and xylem and are **schizogenous cavities.**

Secondary growth: Some of the parenchymatous cells in between the adjacent vascular bundles form interfascicular cambium. Both inter and intrafascicular cambium form a complete ring of cambium. These cambium cells cut cells on the inner side forming secondary xylem and on outer side secondary phloem.

The ring of primary cambium remains active only for a year. The activity of the cambium stops in the **winter season** and again resumes in the following spring. The secondary xylem thus formed clearly shows a number of annual rings. Each annual ring consists of a zone of **spring wood** and **autumn wood.**

Autumn wood: It is formed during autumn season and the cells of this wood are **smaller, squarish and thick.**

Spring wood: It is formed during spring season. The cells of this wood are thinner, large and polygonal. The wood is termed as pycnoxylic (compact and hard).

III. Leaf anatomy

The outline of the needle is variable, in **monofoliar** spur of *P. monophylla*, it is **circular**, in bifoliar spur of *P. sylvestris*, it is **semicircular** and is **triangular** in trifoliar spur of *P. roxburghii*. Internal structure of the needle is same in all species of *Pinus*. Needle shows **xerophytic** characters.

1. **Epidermis:** It has a single-layered, thick-walled epidermis, covered with thick cuticle and is interrupted by sunken stomata throughout the surface **(amphistomatic).**

Stomata: Each stoma has two guard cells and two subsidiary cells. It opens outside into a cavity called vestibule and inside into a substomatal cavity.

2. **Hypodermis:** Below the epidermis is present a few-layered thick sclerenchymatous hypodermis.

3. **Mesophyll:** There is no differentiation into palisade and spongy parenchyma. The cells of this region are thin-walled, parenchymatous, polygonal, compactly arranged, having chloroplasts and starch grains. Peg-like infoldings arise from the inner surface.

4. **Vascular cylinder:** It is surrounded by single-layered endodermis having barrel-shaped cells with **casparian strips.**

5. **Pericycle:** Just below the endodermis is multilayered pericycle having a 'T' shaped mass of sclerenchymatous cells between two vascular bundles.

- The needle of *P. monophylla* has a single vascular bundle whereas in *P. roxburghii*, the number is **two.**

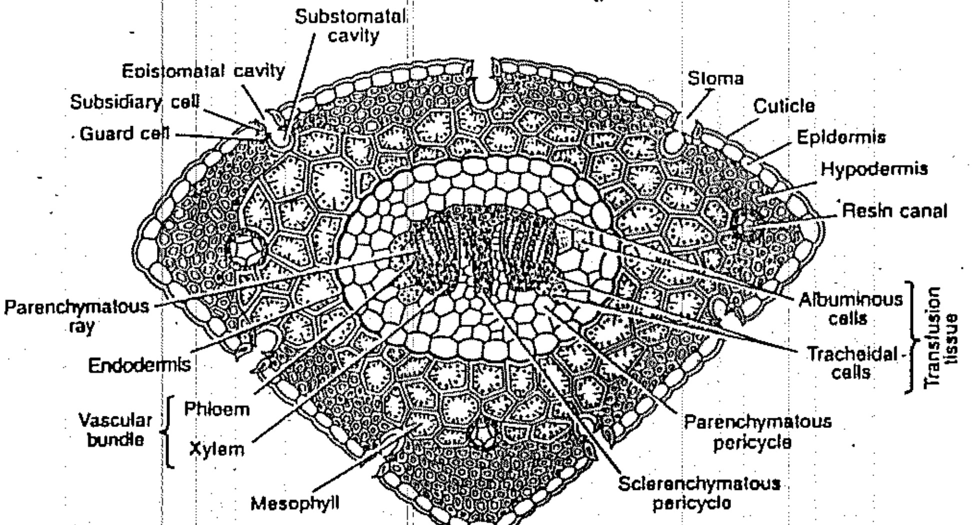


Fig. 14.26. T.S. needle of *Pinus roxburghii*

Transfusion tissue: It has two types of cells:

(a) **Tracheidal cells:** Having bordered pits, **protoplasm** is absent (non-living) and are meant for conduction of water and minerals.

(b) **Albuminous cells:** These are living cells without pits, help in conduction of **food.**

- Vascular bundles are slightly **obliquely placed.** Each vascular bundle is **collateral, open and endarch.**

Reproduction

Pinus reproduces only by means of spores. Vegetative reproduction is lacking. The plants are **monoecious,** *i.e.*, both male and female cones are produced on the **same plant** but on **different branches.**

Pinus is **heterosporous,** *i.e.*, producing two types of spores, **megaspores** and **microspores.** These are produced inside **megasporangium** and **microsporangium,** which are produced on special leaf-like structures **megasporophylls** and **microsporophylls.** The micro and megasporophylls aggregate around the central axis forming a compact structure, known as cone.

The cones are generally **monosporangiate** but rarely **bisporangiate** (a cone with both micro and megasporophylls intermixed), *e.g., P. roxburghii, P. maritima* and *P. montana.*

Male reproductive organs (Male cone)

Male cones are produced earlier than the female cones. These are produced in January in plains and in March on hills. They are produced in clusters in the axil of scale leaves on long shoots, just after the apical bud, without affecting the apical growth. A male cone appears to be a **modified dwarf shoot.**

Male cone is homologous to male flower of angiosperms. Central axis of the cone is equivalent to the thalamus of an angiospermous flower.

Each male cone is an ovoid and small structure, when young, it is 3–4 cm long and 0.65 cm in diameter in *P. roxburghii* having large number of microsporophylls (60–100).

$$\text{Male cone} \xrightarrow[\text{of several}]{\text{composed}} \text{Microsporophylls} \xrightarrow[\text{of}]{\text{consists}} \text{Microsporangia}$$

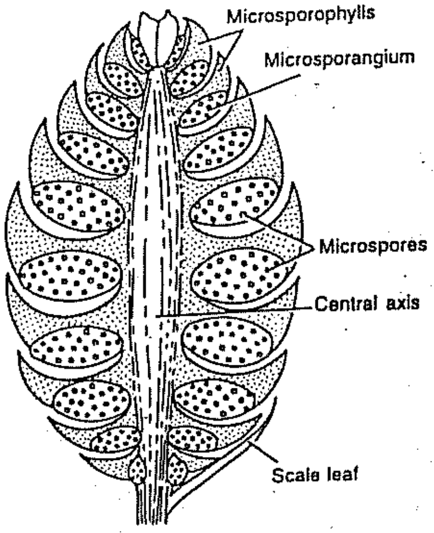


Fig. 14.27. L.S. male cone of *Pinus*

Structure of microsporophyll: Each microsporophyll is small, brown, scaly and triangular having a short stalk and leaf-like expansion called **apophysis.** The apophysis extends upwards overlapping the upper microsporophyll and downwards covering the microsporangia. Dorsal surface of the microsporophyll is sterile, while the ventral surface bears two elongated sac-like structures, microsporangia. A few of the basal microsporophylls are sterile.

Structure of microsporangium: Each microsporangium is a small, sessile and elongated sac-like structure having two-layered wall. Inner to the wall is a nourishing layer known as **tapetum.** In the cavity a large number of dusty and two-winged microspores are present.

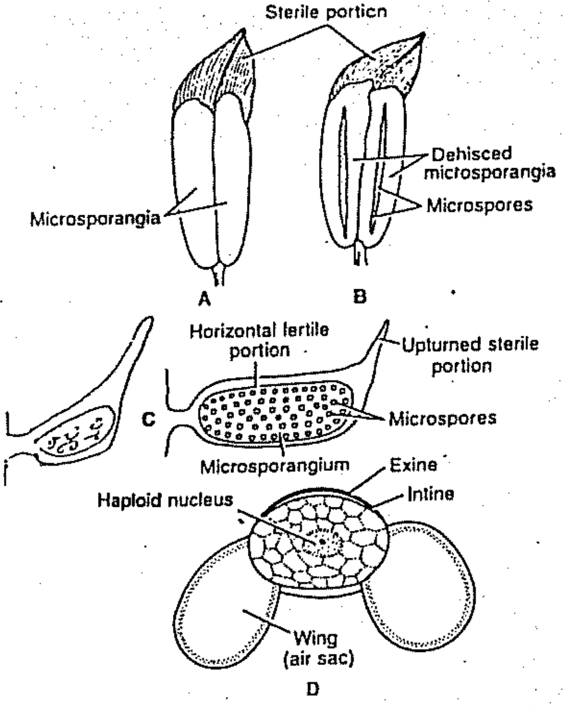


Fig. 14.28. *Pinus:* A. Ventral view of microsporophyll B. Ventral view of microsporophyll with dehisced microsporangia

The dorsal side of the microsporangium has longitudinal slit for dehiscence.

Structure of microspores: Each microspore is a yellow coloured, light structure full of starch grains. It is rounded, uninucleate having two-layered wall. The outer layer is thick, heavily cuticularised called **exine** and the inner is thin delicate and known as **intine.** The exine on the two sides protrudes to form two balloon-shaped **wings** filled with air **(saccus).**

Dehiscence of microsporangium: On maturity the microsporangium wall bursts from the upper side, forming a longitudinal slit. A large number of yellow pollen grains are released. These microspores are released in the month of March. Microspores are produced in such a large number that at the time of their dispersal, yellow clouds of pollen grains are produced, which is called **"shower of sulphur"** or **"shower of golden dust".**

Female cone

The female cones are formed in the month of February in plains and in May on hills. The female cone is produced laterally in the axil of scale leaves on the branches which do not bear male cones. The cones are produced in clusters of 1 to 4 from places where normally dwarf or spur shoots have developed.

These cones begin to develop during winter and are ready for pollination in the following spring. Each female cone matures in **three years**. In the **third year** it matures with ovules. Its sporophylls get separated from each other so that the seeds are dispersed.

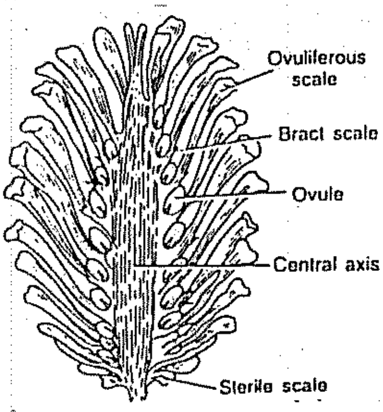

Ovuliferous scale
Bract scale
Ovule
Central axis
Sterile scale

Fig. 14.29. L.S. female cone of *Pinus*

Each female cone is an oval or somewhat elongated structure with an elongated central axis around which a large number of megasporophylls are arranged in an **acropetal** and spiral manner. The female cone represents an inflorescence because the ovule bearing ovuliferous scales are borne on the bract scales which are directly formed on the central axis. Female cones measure 15-20 cm long.

Structure of megasporophyll: Each megasporophyll is differentiated into two parts: Lower part is **bract scale** and upper part is **ovuliferous scale.**

Bract scales: These are small, dry, membranous structures attached with the cone axis directly. These are also known as **carpellary or cover scales.** At the time of maturity, these bract scales become rolled up and thus help in the **dispersal of seeds.**

Ovuliferous scale: This is a woody, brownish structure borne on the dorsal side of the bract scale. Each ovuliferous scale is triangular with narrow basal part and upper broader part in the form of disc, known as **apophysis.** The apophysis appears to be rhomboidal and possesses a small point known as **"umbo".** On the dorsal side, near the base of each ovuliferous scale, are attached two ovules with their micropyles directed towards the cone axis. **Florin** gave the term **"Seed Scale Complex"** to the bract scale along with associated ovuliferous scale.

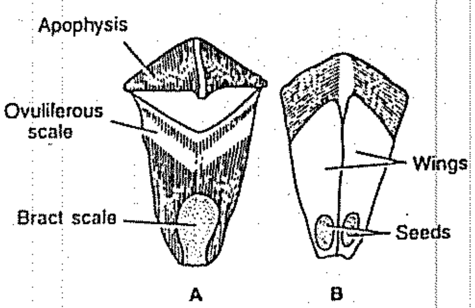

Apophysis
Ovuliferous scale
Bract scale
Wings
Seeds
A
B

Fig. 14.30. *Pinus:* A. Lower (ventral) surface of ovuliferous scale B. Upper (dorsal) surface of the same

Structure of megasporangium (ovule): Each ovule is oval and is **anatropous.** It is having central mass of tissue, called **nucellus,** surrounded by a protective covering, **integument,** which is **bilipped.** The integument is united with the nucellus except at the top where a small opening is left called **micropyle.** A small space is left in the upper region of nucellus below the integument, which is known as **pollen chamber.** Integument is differentiated into 3 layers:

(i) **Outer fleshy layer**
(ii) **Middle stony layer**
(iii) **Inner fleshy layer**

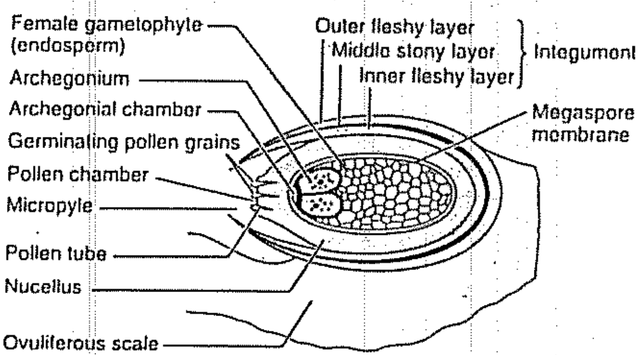

Female gametophyte (endosperm)
Archegonium
Archegonial chamber
Germinating pollen grains
Pollen chamber
Micropyle
Pollen tube
Nucellus
Ovuliferous scale
Outer fleshy layer
Middle stony layer
Inner fleshy layer
Integument
Megaspore membrane

Fig. 14.31. L.S. of mature ovule of *Pinus*

Development of ovule and formation of megaspore (Embryo sac)

At the apex of the nucellus, a hypodermal cell gets enlarged and differentiated, it is called archesporial cell. The archesporial cell divides periclinally into an **upper tapetal cell** which forms **tapetum,** the nourishing layer, and the lower **megaspore mother cell.** This **megaspore mother cell** (sporogenous cell) divides reductionally to form a linear tetrad of haploid megaspores. Out of the four megaspores, three lying towards the micropyle degenerate. The chalazal one matures into a **functional megaspore.**

Pollination

Pollination usually takes place by the end of May in hills and in February or March in plains. In *Pinus* the pollination is **anemophilous,** *i.e.,* pollen grains are carried to the ovule through wind. The wings of the pollen grains are helpful in the dispersal. A secretion oozes out from the micropyle, the pollen grains are entangled in it. Later this fluid is sucked in carrying the pollen grains with it.

- **There is a long interval of about a year between pollination and fertilization.**

The Gametophyte

Microspore and megaspore mother cells act as the last stages of sporophytic generation. These divide reductionally, while inside the sporangia and produce large number of microspores and four megaspores. **These microspores and megaspores represent the first stage of gametophytic generation.**

Development of male gametophyte

Microspore is the beginning of male gametophytic generation. Each microspore is a uninucleate, haploid and biwalled structure (exine and intine) with two laterally expanded wings or saccus. The germination of microspores takes place **"in situ".**

The development of male gametophyte is **partly completed in microsporangium and partly in ovule.**

Development of male gametophyte within the microsporangium (before pollination): The nucleus of microspore divides and a wall is laid down forming a small, upper, lens-shaped cell called **prothallial cell** and a large, lower, apical cell. The apical cell divides again to form a **second prothalial cell** and a large **antheridial cell.** The antheridial cell divides into two parts: a **generative cell,** adjacent to second prothallial cell, and a **tube cell.** Pollen grains are **shed at four-celled stage** (with 2 prothallial cells) and further development takes place in the ovule.

Development of male gametophyte within the ovule (post-pollination changes): The exine of the microspore ruptures, intine comes out to form a **pollen tube.** The tube nucleus moves down into the pollen tube near its tip. The **generative cell** divides into two cells, **stalk cell** and **body cell.** The body cell passes into the pollen tube. The stalk cell also moves towards the lower end of pollen tube. Just before the fertilization, the body cell divides to produce two small, **non-ciliated** and short-lived **male gametes** or **sperms.** The pollen tube is full of starch grains and may be **branched or unbranched.**

Development of female gametophyte

The functional megaspore is the beginning of female gametophytic generation. The development can be studied under the following three stages:

(i) Stage of free nuclear divisions: The megaspore increases in size and its nucleus undergoes many nuclear divisions producing about 2000 free nuclei. A vacuole appears in the centre and pushes all the nuclei towards periphery. Later on this vacuole disappears.

(ii) Stage of wall formation: Wall formation takes place **centripetally** resulting in the formation of multinucleate radially elongated open tubes known as **alveoli.** Cross walls are laid down in such a manner that these alveoli become divided and a multicellular tissue is formed called **female prothallus** or **endosperm.**

- **Endosperm of *Pinus* differs from angiosperms as it is a pre-fertilization structure, while in angiosperms it is a post-fertilization structure.**

(iii) Development of archegonium: Near the micropylar end, **one to five archegonia** are differentiated in the prothallus. Each archegonium at maturity consists of **eight neck cells** arranged in two tiers of four each and a **venter** having a small ventral canal cell and a large egg. The ventral canal cell disorganizes before fertilization.

- Neck canal cells are absent.

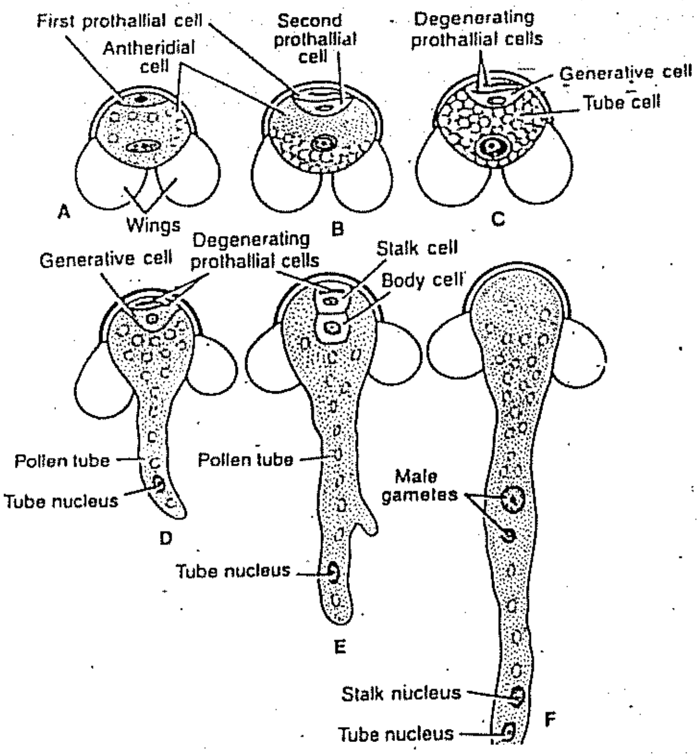


Fig. 14.32. Development of male gametophyte in *Pinus.*

Fertilization

The mode of fertilization was discovered by **Goroschankin** (1883). The fertilization takes place after about a year of pollination. The pollen tube along with tube nucleus, stalk nucleus and two sperms gradually moves downwards to the tip of archegonia. It penetrates the neck and reaches near the egg. The tip of the pollen tube soon bursts and both male gametes become free. Only one of the male gametes fuses with the egg and forms a **zygote,** and the other gamete along with tube and stalk cell disintegrates. Fertilization is usually completed by the end of June. [Fertilization with the help of pollen tube is called **siphonogamy.]**

Development of zygote and formation of embryo

The proembryonal development in *Pinus* was studied by Buchholz (1918). The zygote nucleus divides twice mitotically into four nuclei, which migrate towards the base, and arrange them in one plane. These nuclei divide again forming eight nuclei which become arranged in two tiers of four nuclei each. Wall formation takes place forming lower (apical) tier and

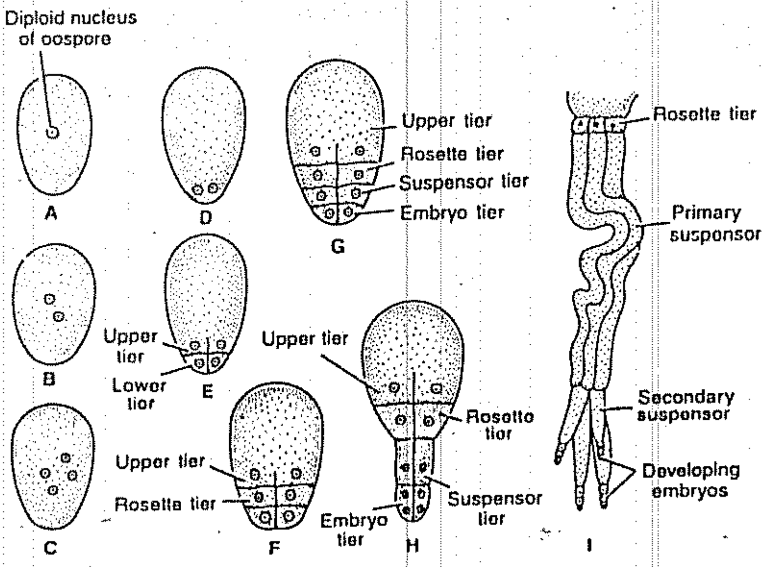

Diploid nucleus of oospore
A
B
C
D
Upper tier
Lower tier
E
Upper tier
Rosette tier
F
Upper tier
Rosette tier
Suspensor tier
Embryo tier
G
Upper tier
Rosette tier
Suspensor tier
Embryo tier
H
Rosette tier
Primary suspensor
Secondary suspensor
Developing embryos
I

Fig. 14.33. A–I. Development of embryo in *Pinus*

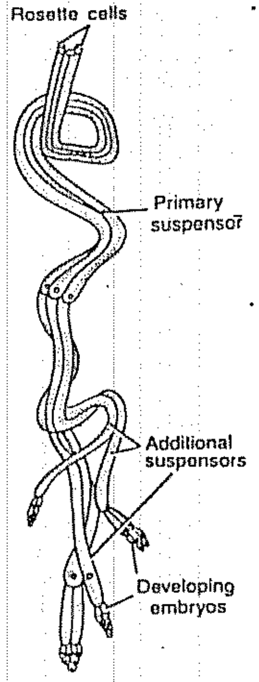

Rosette cells
Primary suspensor
Additional suspensors
Developing embryos

Fig. 14.34. Cleavage polyembryony in *Pinus*

upper (open) tier. Both the tiers divide again giving rise to four-tiered proembryo having sixteen cells.

1. **Embryonal tier (4 cells):** The lowermost tier, which forms the embryo.

2. **Suspensor tier (4 cells):** Above the lower tier which elongates and gives rise to long **suspensors.**

3. **Rossette tier (4 cells):** Above the suspensor tier and mediates between the suspensor tier and nutritive tier.

4. **Nutritive tier (4 cells):** The cells remain open above and provide nutrition to the remaining proembryo.

The cells of the embryonal tier divide and form another tier between them and the primary suspensor cells forming secondary suspensor cells. The process may be repeated again.

All the four cells of the embryonal tier separate from each other and develop independently into **four embryos.** The formation of more than one embryos from one oospore is called **cleavage polyembryony. Simple polyembryony** is also found in *Pinus* (where more than one embryos are formed as a result of fertilization of different archegonia). Although polyembryony is found here but at maturity the seed is having only **one embryo.**

- The mature embryo is having the following parts:
  - (a) **Cotyledons:** 3–18 in number.
  - (b) **Plumule:** Between the cotyledons and gives rise to shoot.
  - (c) **Radicle:** Towards the micropyle and gives rise to root.

Seed

Mature ovule with embryo constitutes **seed.** The seed is covered with hard **seed coat.** The outer layer of the seed coat is **testa** (from **middle stony layer**). Testa encloses a brown, thin membranous **tegmen** (from **inner fleshy layer**). The tegmen surrounds fleshy endosperm.

Inside endosperm is present the embryo. At maturity of seed, a thin layer of ovuliferous scale fuses with testa to form a wing (*i.e.*, **seeds are winged**) which helps in the dispersal of seeds.

- Three generations are represented by seed of *Pinus*:
  - (i) **Old sporophytic generation:** By testa, tegmen and nucellus.

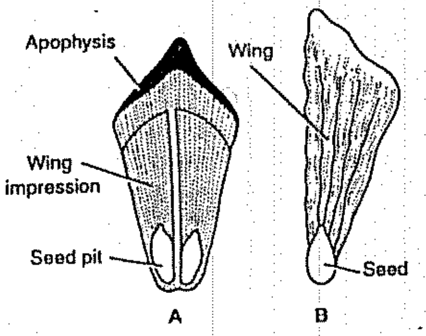

Apophysis
Wing impression
Seed pit
A
Wing
Seed
B

Fig. 14.35. *Pinus*: A. Ovuliferous scale with impressions of seeds and their wings B. A winged seed

(ii) **Gametophytic generation:** By endosperm.

(iii) **Future sporophytic generation:** By embryo.

- The germination of seed is of epigeal type, *i.e.*, the cotyledons come above the ground by the elongation of hypocotyl.

vs/ hypogeal

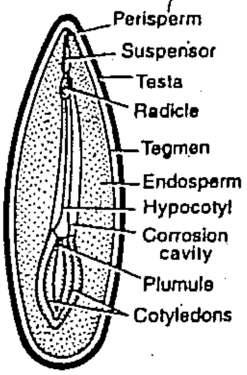

Perisperm
Suspensor
Testa
Radicle
Tegmen
Endosperm
Hypocotyl
Corrosion cavity
Plumule
Cotyledons

Fig. 14.36. L.S. of seed of *Pinus*

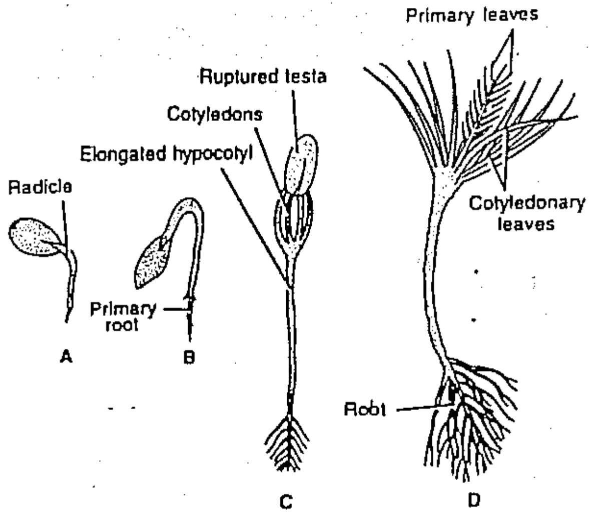

Primary leaves
Ruptured testa
Cotyledons
Elongated hypocotyl
Radicle
Cotyledonary leaves
Primary root
A
B
Root
C
D

Fig. 14.37. **A–D.** Seed germination in *Pinus*

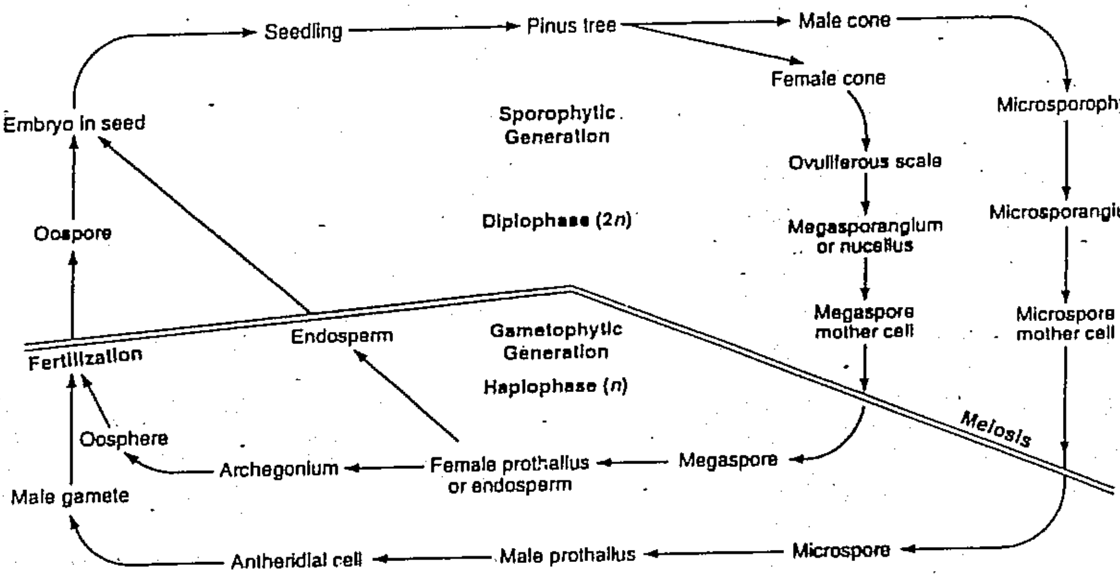

Seedling
Pinus tree
Male cone
Female cone
Embryo in seed
Sporophytic Generation
Microsporophyll
Ovuliferous scale
Oospore
Diplophase (2n)
Microsporangium
Megasporangium or nucellus
Megaspore mother cell
Microspore mother cell
Fertilization
Endosperm
Gametophytic Generation
Haplophase (n)
Meiosis
Oosphere
Archegonium
Female prothallus or endosperm
Megaspore
Male gamete
Antheridial cell
Male prothallus
Microspore

Fig. 14.38. Graphical representation of life cycle of *Pinus*.

MULTIPLE CHOICE QUESTIONS

1. Phanerogams without ovary are:
   (a) Pteridophytes (b) Gymnosperms
   (c) Angiosperms (d) All of these
2. Most primitive seed plants are:
   (a) Gymnosperms (b) Angiosperms
   (c) Pteridophytes (d) None of these
3. Gymnosperms originated in:
   (a) Archaeozoic (b) Mesozoic
   (c) Late Palaeozoic (d) Proterozoic
4. Which is the age of 'higher gymnosperms'?
   (a) Mesozoic (b) Palaeozoic
   (c) Archaeozoic (d) Proterozoic
5. Which of the following is not included in 'Archegoniatae'?
   (a) Bryophytes (b) Pteridophytes
   (c) Gymnosperms (d) Angiosperms
6. Which plant group is not included in 'Embryophyta'?
   (a) Thallophyta (b) Bryophyta
   (c) Spermatophyta (d) None of these
7. Which gymnospermic plant is highly xerophytic, found especially in Sahara desert?
   (a) *Gnetum* (b) *Welwitschia*
   (c) *Ephedra* (d) *Cycas*
8. Most primitive of gymnosperms are:
   (a) Cycadales (b) Bennettitales
   (c) Cycadofilicales (d) Ginkgoales
9. Extremely long roots, the length of which has never been determined, are present in:
   (a) *Cycas* (b) *Pinus*
   (c) *Welwitschia* (d) *Ephedra*
10. Gymnosperms constitute dominant flora of:
    (a) Tropical regions (b) Temperate regions
    (c) Both (a) and (b) (d) None of these
11. Tallest of gymnosperms (or tallest tree) is:
    (a) *Ginkgo* (b) *Sequoia sempervirens*
    (c) *Sequoia gigantea* (d) *Welwitschia*
12. The plant with maximum age is considered to be:
    (a) *Microcycas* (b) *Welwitschia*
    (c) *S. gigantea* (d) *S. sempervirens*
13. Gymnosperms generally have:
    (a) Tap roots (b) Adventitious roots
    (c) Small roots (d) None of these
14. 'Red wood' tree is:
    (a) *Cedrus* (b) *Pinus*
    (c) *Dalbergia* (d) *Sequoia*
15. Which acts as a connecting link between gymnosperms and angiosperms?
    (a) Cycadales (b) Ginkgoales
    (c) Gnetales (d) None of these
16. Vessels in xylem of gymnosperms are:
    (a) Present (b) Absent
    (c) Absent except gnetales (d) Present except gnetales
17. Male gametophytes in gymnosperms have prothallial cells:
    (a) 0 (b) 1
    (c) 1 or more (d) None of these
18. Female cone or strobilus is absent in which gymnosperm?
    (a) *Cycas* (b) *Pinus*
    (c) *Ephedra* (d) None of these
19. Ovule in gymnosperms is generally:
    (a) Anatropous and bitegmic
    (b) Orthotropous and bitegmic
    (c) Orthotropous and unitegmic
    (d) Anatropous and unitegmic
20. Endosperm in gymnosperms is:
    (CBSE 1999; Uttaranchal PMT 2001)
    (a) Generally haploid
    [✓ (b) Always haploid]
    (c) Triploid
    (d) With different ploidy levels
21. Pollination in gymnosperms occurs by:
    (a) Wind (b) Insects
    (c) Water (d) All of these
22. Development of zygote into embryo in gymnosperms is:
    (a) Holoblastic [✓ (b) Meroblastic]
    (c) Both (a) and (b) (d) None of these
23. Polyembryony occurs commonly in:
    (a) Gymnosperms (b) Angiosperms
    (c) Both (a) and (b) (d) None of these
24. Pycnoxylic wood is:
    (a) Compact and hard (b) Soft and loose
    (c) Porous (d) Thick
25. Manoxylic wood is:
    (a) Useless (b) Commercially useful
    (c) Can't say (d) None of these
26. Wood in *Pinus* is:
    (a) Porous (b) Pycnoxylic
    (c) Manoxylic (d) None of these
27. Seeds in gymnosperms represent:
    (a) Single generation (b) 2 generations
    (c) 3 generations (d) None of these
28. Ciliated male gametes are found in:
    (a) *Cycas* (b) *Ginkgo*
    (c) *Pinus* (d) Both (a) and (b)
29. 'Maiden Hair Tree' is: (Pb. PMT 1997; Orissa JEE 2003)
    (a) *Cycas* (b) *Ginkgo*
    (c) *Pinus* (d) *Cedrus*
30. Which is commonly known as 'Living fossil'?
    (CBSE 1996; Raj. PMT 2001)
    (a) *Ginkgo biloba* (b) *Pinus*
    (c) *Cycas* (d) None of these
31. Living fossil of Japan is:
    (a) *Ginkgo* (b) *Cycas revoluta*
    (c) *Cycas circinalis* (d) *Microcycas*
32. 'Christmas tree' is:
    (a) *Ginkgo* (b) *Thuja*
    (c) *Araucaria* (d) *Cupressus*
33. Which is the largest order of modern gymnosperms?
    (a) Gnetales (b) Cycadales
    (c) Coniferales (d) Ginkgoales

*34. Maximum cellulose content is found in:
(a) *Cupressus* (b) Spruce *(Picea)*
(c) *Cedrus* (Deodar) (d) *Pinus*

35. Which is commonly known as 'Jointed fir'?
(a) *Gnetum* (b) *Ephedra*
(c) *Welwitschia* (d) None of these

36. In gymnosperms, triple fusion is:
(a) Present (b) Absent
(c) Present in some (d) All of these

37. 'Sago palm' is: (CPMT 2002)
(a) *Cycas revoluta* (b) *C. circinalis*
(c) *C. rumphii* (d) *Pinus*

38. In gymnosperms pollen drop is:
(a) Pollen dropped by wind (b) Water drop
(c) Secretion of nucellus (d) None of these

39. Both *Pinus* and *Cycas* have:
(a) Motile sperms
(b) Motile and non-motile sperms respectively
(c) Non-motile and motile sperms respectively
(d) Non-motile sperms

40. Gymnosperms differ from most of angiosperms: (CBSE 1993)
(a) In having seeds
(b) In being smaller in system
(c) In having naked ovules
(d) None of the above

*41. In plants, largest egg is found in:
(a) *Cycas* (b) *Pinus*
(c) *Sequoia* (d) *Selaginella*

42. One of the main evolutionary features of alternation of generations from algae in flowering plant is:
(a) Gradual elaboration of sporophyte
(b) Gradual elaboration of gametophyte
(c) Gradual elaboration of both gametophyte and sporophyte
(d) Elimination of sporophyte

43. Gymnosperms lack:
(a) Spores (b) Vegetative reproduction
(c) Sexual reproduction (d) All of these

44. 'Naked seeds' of gymnosperms mean:
(a) Seeds without seed coat
(b) Seeds without tegmen
(c) Seeds not enclosed in ovary wall
(d) All of the above

45. Resin and turpentine are obtained from: (BHU 1991)
(a) *Pinus* (b) *Cycas*
(c) *Cedrus* (d) *Gnetum*

46. 'Chilgoza' is the name of seeds of: (MPPMT 1996)
(a) *Pinus gerardiana* (b) *Pinus longifolia*
(c) *Cycas circinalis* (d) None of these

47. 'Canada balsam' is obtained from:
(a) *Pinus* (b) *Cedrus*
(c) *Abies* (d) *Cupressus*

48. Wood gas and wood tar are obtained from:
(a) *Pinus* (b) *Cycas*
(c) *Abies* (d) *Cedrus*

49. 'Manila copal' an important varnish resin is obtained from:
(a) *Cycas* sps. (b) *Pinus* sps.
(c) *Agathis* sps. (d) *Abies* sps.

50. Which is commonly known as 'Blue pine'?
(a) *Pinus strobus* (b) *P. wallichiana*
(c) *P. merkussii* (d) *P. sylvestris*

51. Which sps. of *Pinus* is found at maximum height?
(a) *P. excelsa* (b) *P. merkussii*
(c) *P. insularis* (d) *P. roxburghii*

52. 'Trifoliar spur' is found in:
(a) *Pinus gerardiana* (b) *P. wallichiana*
(c) *P. sylvestris* (d) None of these

53. Resin canals in cortex and xylem of stem of *Pinus* are:
(a) Schizogenous cavities
(b) Lysigenous cavities
(c) Schizolysigenous cavities
(d) None of the above

54. *Pinus* wood is:
(a) Porous (b) Non-porous
(c) Slightly porous. (d) None of these

55. Vascular bundles in *Pinus* needle are:
(a) Collateral and open (b) Collateral and closed
(c) Radial (d) None of these

56. Transfusion tissue is present in which organ of *Pinus*?
(a) Needle (b) Stem
(c) Root (d) None of these

57. The microsporangia are present on .... surface of microsporophyll in *Pinus:*
(a) Dorsal (b) Ventral
(c) Both (a) and (b) (d) None of these

58. The winged pollens are found in: (MPPMT 2002)
(a) *Cycas* (b) *Pinus*
(c) Both (a) and (b) (d) None of these

59. Phenomenon of 'Sulphur shower' is related with:
(a) *Cycas* (b) *Pinus*
(c) *Ginkgo* (d) None of these

60. Winged seeds are found in:
(a) *Cycas* (b) *Pinus*
(c) *Cedrus* (d) None of these

61. Ovule of *Pinus* is:
(a) Anatropous and unitegmic
(b) Orthotropous and unitegmic
(c) Orthotropous and bitegmic
(d) Amphitropous and bitegmic

62. The interval between pollination and fertilization in *Pinus* is:
(a) 1 day (b) 1 week
(c) 1 month (d) 1 year

63. The number of prothallial cells in male gametophyte of *Pinus* is:
(a) 2 (b) 1
(c) 3 (d) 0

64. Pollination in *Pinus* occurs at .... celled stage of microspores:
(a) 2 (b) 1
(c) 3 (d) 4

65. Endosperm in *Pinus* is:
(a) Pre-fertilization tissue
(b) Post-fertilization tissue
(c) Pre or post-fertilization tissue
(d) None of the above

66. The number of archegonia in *Pinus* ovule is:
(a) 1 (b) 1–5
(c) 2–5 (d) 2–8

67. The number of neck canal cells in archegonium of *Pinus* is:
(a) 4 (b) 6
(c) 1 (d) 0

68. The number of cotyledons in embryo of *Pinus* seed is:
(a) 1 (b) 2
(c) 3–18 (d) 0

69. The germination of seed in *Pinus* is:
(a) Hypogeal (b) Epigeal
(c) Both (a) and (b) (d) None of these

70. Wing of seed of *Pinus* is developed from:
(a) Outer layer of integument
(b) Inner layer of integument
(c) Inner layer of integument and basal part of ovuliferous scale
(d) Only from ovuliferous scale

*71. If chromosome number in nucellus is 20, the number of chromosomes in *Pinus* endosperm is:
(a) 20 (b) 10
(c) 30 (d) 40

72. Foliage leaves or needles of *Pinus* are borne on:
(a) Branches of unlimited growth
(b) Branches of limited growth
(c) Both (a) and (b)
(d) None of the above

74. Megasporophyll of *Pinus* is made of:
(a) Bract scale (b) Ovuliferous scale
(c) Both (a) and (b) (d) None of these

75. The characteristic of gymnosperm ovule is the presence of:
(a) Pollen chamber (b) Integument
(c) Vascular supply (d) Nucellus

76. Pollination in *Cycas* is exclusively by: (CPMT 1990)
(a) Wind (b) Insect
(c) Water (d) Man

77. Gymnosperm of medicinal use is:
(a) *Ephedra* (b) *Pinus*
(c) *Zamia* (d) *Cycas*

78. 'Redwood' of China is:
(a) *Dalbergia* (b) *Sequoia*
(c) *Pinus roxburghii* (d) *P. longifolia*

79. *Pinus* shows:
(a) Cleavage polyembryony (b) Simple polyembryony
(c) Both (a) and (b) (d) None of these

80. *Pinus* has medullary rays:
(a) Homogeneous (b) Heterogeneous
(c) Short (d) Large

81. Endosperm in gymnosperms develops from:
(a) Microspore (b) Megaspore
(c) Secondary nucleus (d) Archegonium

82. How many species of *Cycas* are found in India?
(a) 20 (b) 4
(c) 2 (d) 1

83. Endosperm in gymnosperms is formed: (BHU 1994)
(a) At the time of fertilization
(b) Before fertilization
(c) After fertilization
(d) Along with development of embryo

84. Algal zone is characteristic of: (BHU 1999)
(a) Normal roots of *Cycas* (b) Roots of *Pinus*
(c) Stem of *Cycas* (d) Coralloid roots of *Cycas*

85. How many kinds of leaves do *Cycas* have?
(a) 3 (b) 2
(c) 1 (d) 0

86. *Cycas* trunk is covered with:
(a) Leaves (b) Leaf bases
(c) Scale leaves (d) Both (a) and (b)

87. Ptyxis in *Cycas* is:
(a) Simple (b) Circular
(c) Circinate (d) None of these

88. Inverted 'Omega' (Ω) shaped arrangement of vascular bundles is found in:
(a) *Cycas* leaflet (b) *Cycas* rachis
(c) *Cycas* stem (d) *Cycas* root

89. Transfusion tissue is found in:
(a) *Cycas* leaf (b) *Cycas* leaflet
(c) *Cycas* petiole (d) *Cycas* root

90. The vegetative rep. in *Cycas* occurs by:
(a) Gemma (b) Fragmentation
(c) Bulbils (d) Absent

91. *Cycas* is:
(a) Monoecious (b) Dioecious
(c) Sterile (d) None of these

92. Pollen grains are shed at .... celled stage in *Cycas*. (MH-CET 2003)
(a) 4 (b) 3
(c) 2 (d) 1

93. The number of prothallial cells in male gametophyte of *Cycas* is:
(a) 1 (b) 2
(c) 3 (d) 0

94. *Cycas* ovule is:
(a) Orthotropous and unitegmic
(b) Orthotropous and bitegmic
(c) Anatropous and unitegmic
(d) None of the above

95. How many archegonia develop on one gametophyte of *Cycas*?
(a) 1 (b) 2
(c) 1–5 (d) 3–6

96. Male gametes are largest and visible to naked eyes in:
(a) *Cycas* (b) *Pinus*
(c) *Gnetum* (d) *Ginkgo*

97. The antherozoides in *Cycas* are:
(a) Small, uniciliate and ovoid in shape
(b) Small, lens-shaped and multiciliate
(c) Large, top-shaped and multiciliate
(d) None of the above

98. Germination of *Cycas* seed is: (CPMT 2002)
(a) Epigeal (b) Hypogeal
(c) Both (a) and (b) (d) None of these

99. The number of neck canal cells in the archegonium of *Cycas* is:
(a) 2 (b) 4
(c) 6 (d) 0

100. The number of cotyledons in seed of *Cycas* is:
(a) 1 (b) 2
(c) Many (d) All of these

101. The plant which bears seeds but not fruit is:
(a) Mango (b) Wheat
(c) *Pinus* (d) *Lycopodium*

102. *Cycas* plant is like ....in appearance:
(a) Mango (b) *Acacia*
(c) Date palm (d) *Ficus*

103. Vascular bundles of *Cycas* stem are:
(a) Conjoint
(b) Collateral and closed
(c) Conjoint, collateral and open
(d) Conjoint, collateral and closed

104. Leaves in *Cycas* show:
(a) Hydrophytic characters (b) Xerophytic characters
(c) Mesophytic characters (d) Lithophytic characters

*105. The resin ducts in *Pinus* stem represent: (BHU 1991)
(a) Lysigenous cavity (b) Compound vacuoles
(c) Schizogenous cavity (d) Intercellular space

106. Vessels are present in:
(a) *Cycas* (b) *Pinus*
(c) *Cedrus* (d) *Gnetum*

107. The endosperm in gymnosperms is: (MPPMT 2002)
(a) Haploid (b) Diploid
(c) Triploid (d) Polyploid

108. The smallest gymnosperm known is:
(a) *Cycas revoluta* (b) *Zamia pygmaea*
(c) *Cupressus* sp. (d) *Pinus roxburghii*

109. Among the following, which does not belong to sporophyte generation in *Pinus*? (BHU 1997)
(a) Dwarf shoot (b) Long shoot
(c) Roots (d) Endosperm

110. The coralloid roots of *Cycas* have an algal zone and the alga present in this zone is: (CPMT 1991)
(a) *Ulothrix* (b) *Anabaena*
(c) *Spirogyra* (d) *Nostoc*

111. Transfusion tissue is present in the leaves of:
(a) *Dryopteris* (b) *Cycas*
(c) *Pinus* (d) Both *Cycas* and *Pinus*

112. Largest sperms (spermatozoids) are found in:
(a) *Pinus* (b) *Cycas*
(c) *Selaginella* (d) *Dryopteris*

113. In female gametophyte of *Cycas*, number of archegonia present is:
(a) More than ten (b) Two to eight
(c) One (d) None of these

114. Largest ovule is that of:
(a) *Cocos* (b) *Gnetum*
(c) *Pinus* (d) *Cycas*

115. Difference between gymnosperm and angiosperm is that in gymnosperms: (CPMT 1993)
(a) Seeds are absent
(b) Ovary is absent
(c) Companion cells are absent
(d) Sieve tubes are absent

116. Antherozoids of *Cycas* are:
(a) Multiciliate (b) Aflagellate.
(c) Triflagellate (d) Biflagellate

117. The neck canal cells are absent in the archegonia of: (Re. Ex. CPMT 1991)
(a) *Cycas* (b) Bryophytes
(c) *Funaria* (d) Pteridophytes

118. Gymnosperms are the plants which: (AIIMS 1992)
(a) Bear flowers
(b) Bear fruits but no vascular tissue
(c) Produce seeds in cones
(d) Do not produce seeds in cones

119. Megasporophylls of ferns and gymnosperms are comparable to which structure of angiosperms?
(a) Stamens (b) Ovules
(c) Carpels (d) Megasporophylls

120. "Kail" is:
(a) *Pinus roxburghii* (b) *P. wallichiana*
(c) *P. gerardiana* (d) *P. insularis*

121. Stem of *Cycas* contains:
(a) Pycnoxylic wood (b) Manoxylic wood
(c) Heart wood (d) Porous wood

122. *Cycas* has an embryo with two cotyledons yet it is not classified as dicotyledonous plant because: (CBSE 2001)
(a) It has compound leaves (b) It bears megasporophylls
(c) It looks like a palm tree (d) Its ovules are naked

123. The gymnosperms differ from angiosperms in:
(a) Habit (b) Habitat
(c) Presence of wood (d) Absence of ovary

124. Number of ovules present on megasporophyll of *Cycas* is:
(a) Only one (b) One pair
(c) 1–6 pairs (d) Absent

125. Multiciliate male gametes (spermatozoids) are found in: (CPMT 1999; BHU 1999)
(a) Angiosperms (b) *Cycas*
(c) *Ulothrix* (d) *Funaria*

126. Wings in *Pinus* seeds develop from: (MPPMT 1993)
(a) Bract scales (b) Ovuliferous scales
(c) Cone axis (d) Seed coat

127. In *Cycas*:
(a) Male strobilus and megasporophylls occur on the same individual
(b) The same cone consists of both micro and megasporophylls
(c) The same sporophyll bears microsporangia and ovules
(d) Male strobilus (cone) and megasporophylls occur on separate individuals

*128. Birbal Sahni discovered a fossil plant from Rajmahal Hills. It belongs to:
(a) Angiosperms (b) Gymnosperms
(c) Bryophyta (d) Pteridophyta

129. Coralloid roots are found in:
(a) *Pinus* (b) *Lycopodium*
(c) *Cycas* (d) *Dryopteris*

130. Sperms of *Cycas*: (CPMT 1991)
(a) Are large and non-ciliate
(b) Are small and non-motile
(c) Are very large and have numerous spirally arranged cilia
(d) Are very small and have two flagella

131. Cedar wood oil is obtained from the heart wood of: (AIIMS 1991)
(a) *Thuja occidentalis* (b) Angiosperms
(c) *Cedrus* (d) *Juniperus virginiana*

132. *Cycas* is a gymnosperm because:
(a) It forms seeds
(b) It bears pollen grains
(c) It lacks ovary but has exposed ovules
(d) Its xylem consists of tracheids

133. Secondary wood in *Cycas* is devoid of:
(a) Tracheids (b) Vessels
(c) Protoxylem (d) Metaxylem

134. Early embryogeny in *Cycas* is characterised by: (Re. Ex. CPMT 1991)
(a) Absence of suspensor cell
(b) Presence of expanded free nuclear division
(c) Reduced free nuclear division
(d) Many cotyledons

135. Which of the following characters does not hold true for *Pinus*?
(a) Bracts and ovuliferous scales
(b) Embryo with two cotyledons
(c) Resin canals in needles
(d) Tracheids with bordered pits

*136. If the haploid number of chromosomes in gymnosperms (*Pinus*) is 12, what will be the number of chromosomes in its root and endosperm? (MPPMT 2000)
(a) 12, 12 (b) 12, 24
(c) 24, 12 (d) 24, 36

137. Largest ovules (or largest gametes or longest plants) are found among:
(a) Monocots (b) Dicots
(c) Gymnosperms (d) Angiosperms

138. In gymnosperms, the xylem lacks:
(a) Fibres (b) Tracheids
(c) Vessels (d) Parenchyma

139. Which of the following structures in *Pinus* are haploid?
(a) Megaspore, integument, root
(b) Endosperm, megaspore, pollen grain
(c) Pollen grain, leaf, root
(d) Megaspore, endosperm, embryo

140. In *Cycas*, the first formed cambial ring is short-lived and new cambial ring is formed every year in the pericycle or cortex. Wood formed by this method is:
(a) Polyxylic (b) Monoxylic
(c) Pycnoxylic (d) Manoxylic

141. Which of the following is not the characteristic feature of *Cycas?*
(a) Naked ovules (b) Circinate vernation
(c) Vessels in xylem (d) Girdling leaf traces

142. In the plants of *Cycas*, the male cone lacks:
(a) Microspore (b) Microsporophyll
(c) Microsporangium (d) Nucellus

143. Dwarf shoots of *Pinus* have:
(a) 1–4 leaves (b) 1–5 leaves
(c) 2–4 leaves (d) 2–5 leaves

144. Which of the following is the tallest among gymnosperms?
(a) *Ginkgo* (b) *Cedrus*
(c) *Pinus trifolia* (d) *Cycas revoluta*

145. Monkey's puzzle is the common name of:
(a) *Pinus longifolia* (b) *Cycas revoluta*
(c) *Gnetum gnemon* (d) *Araucaria imbricata*

146. *Pinus*: (BHU 1991)
(a) Bears flowers
(b) Exhibits no vascular tissue
(c) Produces seeds in cones
(d) Does not produce seeds in cones

147. Winged seeds are found in:
(a) *Pinus* sps. (b) *Cycas* sps.
(c) *Papaver* sps. (d) None of these

*148. The girdle leaf traces in *Cycas* go to leaves:
(a) After making a semi-circle
(b) After making a complete circle
(c) After making two circles
(d) None of the above

149. *Cycas* and *Pteris* resemble each other in the presence of:
(a) Vessels (b) Seeds
(c) Ciliated sperms (d) Cambium

150. Polyembryony seen in *Cycas* is:
(a) Potential true polyembryony
(b) Potential true polyembryony and cleavage polyembryony
(c) Adventive polyembryony
(d) All of the above

151. The gymnosperms resemble angiosperms in having:
(a) Ciliated sperms
(b) Presence of archegonia
(c) Presence of ovules
(d) Presence of manoxylic wood

*152. The life cycle in *Pinus* is:
(a) Diplontic (b) Haplodiplontic
(c) Haplontic (d) Diplobiontic

153. Which of the following is called 'a living fossil'? (CBSE 2003)
(a) *Pinus* (b) *Cycas*
(c) *Metasequoia* (d) *Ephedra*

154. In gymnosperms, the endosperm is formed by the:
(a) Fusion of one male gamete with two polar nuclei
(b) Fusion of one male gamete with one polar nuclei
(c) Fusion of male gametes with the egg
(d) Germination of a megaspore

155. Which of the following characters can be used to distinguish gymnosperms from angiosperm? (AIIMS 1991)
(a) Presence of pollen chamber in gymnosperms
(b) Presence of stomata in angiosperms
(c) Presence of naked ovules in gymnosperms
(d) None of the above

156. In *Cycas* the pollen grains are shed at:
(a) One-celled stage (b) Two-celled stage
(c) Three-celled stage (d) Four-celled stage

157. The number of cotyledons in *Pinus* seeds are:
(a) Two (b) Three
(c) Many (d) Fleshy

158. *Pinus* differs from mango in having: (CBSE 1993)
(a) Presence of wood
(b) Ovules not enclosed in ovary
(c) Tree habit
(d) Green leaves.

159. The endosperm of gymnosperms is haploid because:
(a) It is a gametophytic tissue
(b) Double fertilization does not take place
(c) It is not the product of triple fusion
(d) All the above reasons

160. In *Cycas*, during secondary growth large amount of parenchyma is cut off in the xylem. This wood is known as:
(a) Porous (b) Non-porous
(c) Manoxylic (d) Pycnoxylic

161. Each leaf of *Cycas* is supplied by:
(a) Two direct traces and two girdle traces
(b) A number of direct traces and two girdle traces
(c) A number of direct traces and a number of girdle traces
(d) Two direct traces and a number of girdle traces

162. The secondary growth in stem of *Cycas* is brought about by: (CPMT 1990)
(a) Persistent cambium
(b) Short lived cambium
(c) Number of cambia produced in succession
(d) Isolated strips of cambium

163. The coralloid roots of *Cycas* have: (CPMT 1993)
(a) Nitrogen-fixing bacteria (b) Blue-green algae
(c) Ants (d) Mycorrhizal fungus

*164. In which of the following, sexual reproduction is possible without water?
(a) *Ulothrix* (b) *Funaria*
(c) *Dryopteris* (d) *Cycas*

165. The tracheids of *Cycas* have:
(a) Uniseriate bordered pits
(b) Biseriate bordered pits
(c) Multiseriate bordered pits
(d) No bordered pits

166. The neck cells in the archegonium of *Cycas* are: (CPMT 1990)
(a) One (b) Two (c) Four (d) Six

*167. The explanation for occurrence of ciliated motile sperms in xerophytic *Cycas* is:
(a) It is a vestigeal character indicating the pteridophytic ancestry of *Cycas*
(b) It is a functional character, the pollen chamber of *Cycas* is filled with water and the sperms must be ciliated for swimming
(c) When the pollen grain and ovules of *Cycas* fall on the ground, the pollen germinates and sperms swim in rain water to reach the ovule
(d) The cilia are a xerophytic character like hair

168. The leaves of *Cycas* are:
(a) Unipinnately compound with parallel venation
(b) Unipinnately compound with unicostate reticulate venation
(c) Unipinnately compound with multicostate reticulate venation
(d) Unipinnately compound with no venation

169. Which is absent in coralloid roots of *Cycas*?
(a) Root hair and casparian band in endodermis
(b) Root cap and casparian band in endodermis
(c) Both root hair and root cap
(d) None of the above

170. Which species of *Cycas* is having largest male cones?
(a) *Cycas revoluta* (b) *C. rumphii*
(c) *C. circinalis* (d) *C. beddomei*

171. Male and female *Cycas* plants show which type of growth?
(a) Monopodial in both
(b) Sympodial in both
(c) Monopodial in male and sympodial in female plant
(d) Sympodial in male and monopodial in female plant

172. A single microsporophyll in *Cycas revoluta* is having about .... sporangia:
(a) 1000 (b) 2000
(c) 100–300 (d) 400–500

173. Seeds of *Cycas* are dispersed by:
(a) Wind (b) Birds (c) Water (d) Insects

174. Radicle (embryonic root) is covered by a hard pod-like covering 'coleorhiza' in:
(a) *Cycas* (b) *Pinus*
(c) Both (a) and (b) (d) None of these

*175. Triangular outline of needle is found in:
(a) *Pinus roxburghii* (b) *P. sylvestris*
(c) *P. monophylla* (d) None of these

176. 'Bars of Sanio' are present in tracheids of:
(a) *Cycas* (b) *Pinus*
(c) Both (a) and (b) (d) None of these

177. Stomata present on needles of *Pinus* are:
(a) Sunken and syndetocheilic
(b) Sunken and haplocheilic
(c) Normal and syndetocheilic
(d) Normal and haplocheilic

178. The dwarf shoots of *Pinus wallichiana* are:
(a) Monofoliar (b) Bifoliar
(c) Trifoliar (d) Pentafoliar

179. Wood of *Pinus* is:
(a) Manoxylic and monoxylic
(b) Pycnoxylic and monoxylic
(c) Manoxylic and polyxylic
(d) Pycnoxylic and polyxylic

180. The microspore tetrads of *Cycas* and *Pinus* are:
(a) Tetrahedral tetrad in both
(b) Isobilateral tetrad in both
(c) Tetrahedral in *Cycas* and isobilateral in *Pinus*
(d) Linear tetrad in both

181. *Pinus* female cone matures completely in:
(a) 1 year (b) 1½ years
(c) 2 years (d) 3 years

182. The wall of mature pollen grains in *Pinus* is:
(a) Single layered (b) Two layered
(c) Three layered (d) Four layered

183. The male gametes of *Pinus* species are:
(a) Non-ciliated (b) Uniciliated
(c) Biciliated (d) Multiciliated

184. The term 'saccus' is used for:
(a) Wings of seeds of *Pinus*
(b) Wings of pollen grains of *Pinus*
(c) Prothallial cell of pollen grain of *Pinus*
(d) Intine of pollen grain of *Pinus*

185. Wings in pollen grains of *Pinus* develop from:
(MPPMT 1997; CET Chandigarh 1997)
(a) Exine or cappa (b) Intine or tenuitas
(c) Exointine or capulla (d) Sporangial wall

186. Seeds of *Pinus* are dispersed by:
(a) Wind (Anemochorous) (b) Birds (Ornithochorous)
(c) Animals (Zoochorous) (d) Water (Hydrochorous)

187. Testa in seed of *Pinus* develops from:
(a) Whole integument
(b) Outer fleshy layer of integument
(c) Middle stony layer of integument
(d) Inner fleshy layer of integument

188. Pericycle of *Pinus* needle contains:
(a) Parenchymatous cells (b) Tracheidal cells
(c) Albuminous cells (d) All of these

189. Pollen tube in *Pinus* is:
(a) Unbranched (b) Branched
(c) Both (a) and (b) (d) None of these

190. Which of the following orders has only fossil gymnosperms?
(a) Ginkgoales (b) Coniferales
(c) Cycadofilicales (d) Gnetales

191. Most gymnosperms have:
(a) Both archegonia and antheridia
(b) Archegonia but no antheridia
(c) Antheridia but no archegonia
(d) No antheridia nor archegonia

192. Male gametophyte in gymnosperms is represented by:
(a) Microsporangium (b) Microspore
(c) Nucellus (d) Spore dyad

193. The term 'gymnosperm' was first introduced by:
(a) Theophrastus (b) Brown
(c) Bauhin (d) Caesalpino

194. Oldest living member of seed plants is:
(a) *Cycas* (b) *Sequoia*
(c) *Ginkgo* (d) *Metasequoia*

195. Which of the following gymnosperms is not present in India?
(a) *Cycas* (b) *Ginkgo*
(c) *Welwitschia* (d) *Cedrus*

*196. Which gymnosperm is having 'bitegmic ovules'?
(a) *Cycas* (b) *Ginkgo*
(c) *Gnetum* (d) *Taxus*

197. Which wood is used for making pencils?
(a) *Juniperus* (b) *Cedrus*
(c) *Abies* (d) *Pinus*

198. Gymnosperm as separate group was recognized by:
(a) Brown (b) Bentham and Hooker
(c) Eichler (d) Chamberlain

199. 'Vivipary' phenomenon has been observed in which gymnosperm?
(a) *Agathis alba* (b) *Pinus wallichiana*
(c) *Ephedra trifurcata* (d) *Cycas circinalis*

*200. Gymnosperm of medicinal importance in treatment of cold, cough, etc., is: (DPMT 2001)
(a) *Cycas* (b) *Ephedra* (c) *Juniperus* (d) *Abies*

201. In Andaman and Nicobar islands, common species of *Cycas* is:
(a) *C. circinalis* (b) *C. revoluta*
(c) *C. beddomei* (d) *C. rumphii*

202. During pollination, pollen grains in *Cycas* are trapped by:
(a) Malic acid drop
(b) Pseudostigma
(c) Stigma
(d) Viscous fluid in pollen chamber

203. Source of male gametes in *Cycas* is:
(a) Body cell (b) Tube cell
(c) Prothallial cell (d) None of these

204. Xylem condition in most of the part of *Cycas* rachis is:
(a) Endarch (b) Exarch
(c) Pseudomesarch (d) Both (a) and (b)

205. How much time is generally taken by the pine plant from pollination to fertilization?
(MPPMT 1995; PMET Punjab 2003)
(a) Four months (b) Fifteen months
(c) Two years (d) Four years

206. Which of the following represents the gametophytic phase in *Pinus*? (MPPMT 1994)
(a) *Pinus* plant (b) Micro and megaspores
(c) Zygote (d) Male and female cones

207. Edible dry fruit from a gymnosperm is: (CPMT 1994)
(a) Cashewnut (b) Coconut
(c) Chilgoza (d) Groundnut

208. Number of cotyledons in an embryo of *Zea*, *Cycas* and *Pinus* are respectively: (BHU 1994)
(a) 1, 2, many (b) 1, 1, 2
(c) 1, 2, 2 (d) 2, 2, many

209. The false character with respect to *Pinus* is the presence of:
(a) Resin canals (b) Bordered pits
(c) Bract scales (d) Dicot embryo

210. What causes sulphur clouds in temperate climate?
(a) Male gametophytes of pine
(b) Male gametes of pine
(c) Volatile resin and turpentine
(d) Sulphur bacteria

211. Which of the following characters are true for *Cycas*?
(a) Wood is polyxylic and manoxylic
(b) Presence of sponge-like coralloid roots
(c) Male and female organ are present on separate plants
(d) All of the above

212. Mycorrhizae of *Pinus* are of appearance:
(a) Tuberous type (b) Nodulated type
(c) Coralloid type (d) All of these

213. Different environmental factors, which force xerophytism on *Pinus* are:
(a) Thin soil cover (b) Seasonal rainfall
(c) Slope (d) All of these

*214. *Sequoiodendron giganteum* is called:
(a) Flame of the forest (b) Father of the forest
(c) Tiny shrub (d) None of these

215. A single 3-layered integument covers the nucellus in:
(a) Bryophytes (b) Pteridophytes
(c) Gymnosperms (d) Angiosperms

216. In gymnosperms, the reproductive organs are present on:
(a) Cones (b) Strobili
(c) Both (a) and (b) (d) None of these

217. In gymnosperms, vascular strand is made of:
(a) Conjoint vascular bundles
(b) Open vascular bundles
(c) Collateral vascular bundles
(d) All of the above

218. Seed of *Pinus* species is: (MPPMT 1997)
(a) Uneconomic and non-endospermic
(b) Abaxial and rounded
(c) Adaxial and endospermic
(d) Hypogeal and monocotyledonous

219. *Pinus* species is: (MPPMT 1997, 99)
(a) Monoecious (b) Dioecious
(c) Both (a) and (b) (d) None of these

220. Winged pollen grains of *Pinus* species are produced in: (MPPMT 1997)
(a) Pollen chamber (b) Anther
(c) Tapetum (d) Microsporangium

221. In *Pinus*, male and female reproductive structures occur: (MPPMT 1996)
(a) On different branches of same plant
(b) On different plants
(c) On same branch
(d) None of the above

222. From the pith of stem of *Cycas revoluta* "sago" is obtained which is used as food article for a patient with stomach disorders because: (AIIMS 1997)
(a) It is much tastier
(b) Its nutritive value is very high
(c) It is having less amount of starch and easily digestable
(d) It is a cheap food article

223. *Pinus* species are: (AIIMS 1997)
(a) Monoecious and autoecious
(b) Dioecious
(c) Both monoecious and dioecious
(d) None of the above

224. In gymnosperms the seeds are naked because they lack: (MPPMT 1996)
(a) Integument (b) Nucellus
(c) Pericarp (d) Perianth

225. In gymnosperms the only mode of pollination is: (CET Chandigarh 1997)
(a) Hydrophily (b) Zoophily
(c) Entomophily (d) Anemophily

226. A microspore of *Pinus* has: (CET Chandigarh 1992)
(a) No wings (b) 2 balloon-like wings
(c) 3 swollen wings (d) Non-flated wings

227. Winged pollen grains are found in: (Pondicherry 1992)
(a) *Cycas* (b) *Pinus*
(c) *Pteris* (d) *Selaginella*

228. *Pinus* is a gymnosperm because: (AMU 1991; CBSE 1991)
(a) It is a large tree
(b) It is pollinated by wind
(c) It has exposed naked ovules
(d) It produces seeds and it has narrow leaves

229. Manoxylic wood is: (AIIMS 1993)
(a) Compact and hard
(b) Loose and soft
(c) Having several growth rings
(d) Wood derived from persistent cambium

230. In which of the following fertilization or reproduction is possible without water? (AIIMS 1992; BHU 1992)
(a) *Ulothrix* (Algae)
(b) *Funaria* (Bryophytes)
(c) *Dryopteris* (Pteridophytes)
(d) *Cycas* (Gymnosperms)

231. Which of the following is the best explanation of the excurrent (pyramidal) shape of *Pinus* (the branches giving the plant the appearance of a tall cone)? (BHU 1997)
(a) Competition among adjoining trees for sunlight
(b) The effect of auxins on growth of stem tips
(c) Adaptation for wind pollination
(d) Efficiency of water transport from ground to leaves

232. In *Pinus* the approximate time for fertilization after pollination is: (BHU 1994)
(a) Only a few hours (b) About one year
(c) Only a few days (d) Only a few weeks

233. Turpentine is obtained from: (CBSE 1992)
(a) Angiosperm wood
(b) Angiospermous flowers
(c) Gymnospermous wood or *Pinus*
(d) Ferns

234. How many living genera of gymnosperms are present in India?
(a) 16 (b) 10 (c) 5 (d) 2

235. Generative cell in the male gametophyte of *Pinus* divides to form:
(a) Antheridial cell
(b) Prothallial cell and body cell
(c) Stalk cell and body cell
(d) Only body cell

236. Characters of both conifers and cycads are found in: (AMU 1997)
(a) *Ginkgo* (b) *Ephedra* (c) *Cupressus* (d) *Tsuga*

237. The main character of a gymnospermic plant, *e.g.*, *Cycas* is: (CPMT 1991)
(a) Presence of xylem
(b) Presence of circinate vernation
(c) Presence of traces of leaves
(d) Presence of naked exposed ovules

238. Which one of the following gymnosperms is said to have double fertilization? (AMU 1997)
(a) *Ginkgo* (b) *Ephedra* (c) *Cycas* (d) *Pinus*

239. Archegoniates include: (BHU 1993)
(a) Algae, bacteria and fungi
(b) Algae, lichens

(c) Bryophytes, pteridophytes and gymnosperms
(d) Pteridophytes, gymnosperms and angiosperms

240. "Chilgoza" a dry fruit in the market comes from a species of: (BHU 1995)
(a) *Cycas* (b) *Pinus* (c) *Gnetum* (d) Mango

241. The microsporangium in *Cycas* microsporophylls are present on: (AIIMS 1996)
(a) Adaxial side (b) Abaxial side
(c) Along the margins (d) In the axils

242. Tracheophyta includes: (Pb. PMT 1997)
(a) Bryophytes only
(b) Pteridophytes only
(c) Gymnosperms and angiosperms only
(d) Pteridophytes, gymnosperms and angiosperms

243. In gymnosperms seed is said to be naked because these: (CPMT 1998)
(a) Do not contain ovule
(b) Do not have ovary
(c) Do not contain endosperm
(d) Do not contain starch

244. Largest ovule is found in: (CPMT 1998; AFMC 2002)
(a) *Cycas* (b) *Pinus*
(c) *Taxus* (d) Watermelon

245. Largest sperms in the plant world are found in: (CBSE 1998)
(a) *Thuja* (b) *Pinus* (c) Banyan (d) *Cycas*

246. Which of the following statements about *Cycas* is incorrect? (CBSE 1998)
(a) Its roots contain some blue-green algae
(b) It does not have a well organized female flower
(c) It has circinate vernation
(d) Its xylem is mainly composed of xylem vessels

247. Small tracheids and parenchyma in *Cycas* constitute: (CPMT 1999)
(a) Transfusion tissue (b) Coralloid roots
(c) Endosperm (d) Mesophyll tissue

248. Seed ferns belong to: (BHU 1999)
(a) Coniferales (b) Cycadales
(c) Pteridospermales (d) Ginkgoales

249. Gymnosperms are: (BHU 1999)
(a) Annuals (b) Biennials
(c) Perennials (d) All of these

250. In which of the following plants, seed is obtained but fruit does not occur? (AIIMS 1999)
(a) Date palm (b) Pine
(c) Guava (d) None of these

251. Largest ovules are found in: (CBSE 2000)
(a) Gymnosperms (b) Angiosperms
(c) Pteridophytes (d) Dicots

252. Male cone of *Cycas* consists of: (CPMT 2000)
(a) Megasporophylls (b) Microsporophylls
(c) Archegonia (d) None of these

*253. The wood of *Pinus* is: (MPPMT 2000)
(a) Pycnoxylic and homoxylous
(b) Pycnoxylic and heteroxylous
(c) Manoxylic and homoxylous
(d) Manoxylic and heteroxylous

254. In *Cycas*, inverted omega-shaped vascular bundles are found in: (CPMT 2001)
(a) Rachis (b) Leaflet (c) Stem (d) Root

255. Cones and flowers are similar as: (Manipal 2001)
(a) They are bright and showy
(b) Both are reproductive organs
(c) Both attract insects for pollination
(d) Both help in dispersal of seeds

256. In which portion of *Cycas*, diploxylic vascular bundles are found? (AIIMS 2000; EAMCET 2002)
(a) Root (b) Stem
(c) Leaflet (d) Rachis and leaflet

*257. Which of the following plants has not changed for several thousands of years?
(a) *Gnetum* (b) *Dryopteris*
(c) *Ginkgo* (d) Palms

258. Which of the following is correct regarding *Cycas*? (AIIMS 2001)
(a) The same sporophyll bears microsporangia and ovules
(b) A single cone consists of both mega and microsporophylls
(c) Male strobilus and megasporophylls occur on the same plant
(d) Male strobilus and megasporophylls occur on separate plants

259. Vascular bundles in *Pinus* stem are: (MPPMT 2001)
(a) Radial (b) Collateral and closed
(c) Collateral and open (d) Bicollateral

260. In *Cycas*, male gametes are produced in the pollen tube by the division of which of the following cells? (BHU 2001)
(a) Body cell (b) Stalk cell
(c) Tube cell (d) Prothallial cell

261. Seed of *Pinus* possesses: (CET J&K 2002)
(a) Parent sporophyte as seed coat, perisperm, etc.
(b) Gametophyte like endosperm
(c) Future sporophyte like embryo
(d) All of the above

262. The medicine of cancer 'Taxol' is obtained from bark of which plant? (Raj. PMT 2001)
(a) *Taxus* (b) *Ephedra* (c) *Cycas* (d) *Picea*

263. Turpentine oil is obtained from: (Raj. PMT 2001)
(a) Coal (b) Petroleum
(c) Cedarwood (d) *Pinus*

264. Megasporophyll of *Cycas* has the same nature as: (AIIMS 2002)
(a) Stamen (b) Sepal (c) Petal (d) Carpel

265. Fern character in *Cycas* is: (PMET Punjab 2003)
(a) Coralloid roots (b) Tap root system
(c) Circinate vernation (d) Reticulate venation

266. *Pinus* produces: (Manipal 2003)
(a) Naked seeds in cones (b) Flowers
(c) No seeds (d) No vascular tissues

267. The terminal sterile portion of an organ, considered to be an equivalent of angiosperms stamen in *Cycas* is known as: (EAMCET 2003)
(a) Columella (b) Hapteron (c) Paraphysis (d) Apophysis

268. The lateral movement of water in a leaflet of *Cycas* takes place by: (MH-CET 2003)
(a) Xylem (b) Tracheas
(c) Transfusion tissue (d) Lateral tissue

ANSWERS

1—b	2—a	3—c	4—a	5—d	6—a	7—b	8—c	9—c	10—b	11—b	12—c
13—a	14—d	15—c	16—c	17—c	18—a	19—c	20—b	21—a	22—b	23—a	24—a
25—a	26—b	27—c	28—d	29—b	30—a	31—b	32—c	33—c	34—b	35—b	36—b
37—a	38—c	39—c	40—c	41—a	42—a	43—b	44—c	45—a	46—a	47—c	48—a
49—c	50—b	51—a	52—a	53—a	54—b	55—a	56—a	57—b	58—b	59—b	60—b
61—a	62—d	63—a	64—d	65—a	66—b	67—d	68—c	69—b	70—d	71—b	72—b
73—b	74—c	75—a	76—a	77—a	78—d	79—c	80—b	81—b	82—b	83—b	84—d
85—b	86—d	87—c	88—b	89—b	90—c	91—b	92—b	93—a	94—a	95—d	96—a
97—c	98—b	99—d	100—b	101—c	102—c	103—c	104—b	105—c	106—d	107—a	108—b
109—d	110—b, d	111—d	112—b	113—b	114—d	115—b	116—a	117—a	118—c	119—c	120—b
121—b	122—d	123—d	124—c	125—b	126—b	127—d	128—b	129—c	130—c	131—d	132—c
133—b	134—b	135—b	136—c	137—c	138—c	139—b	140—a	141—c	142—d	143—b	144—c
145—d	146—c	147—a	148—a	149—c	150—a	151—c	152—b	153—b	154—d	155—c	156—c
157—c	158—b	159—d	160—c	161—a	162—c	163—b	164—d	165—c	166—b	167—a	168—d
169—c	170—c	171—d	172—a	173—b	174—a	175—a	176—b	177—b	178—d	179—b	180—a
181—d	182—c	183—a	184—b	185—a	186—a	187—c	188—d	189—c	190—c	191—b	192—b
193—a	194—c	195—c	196—c	197—a	198—a	199—c	200—b	201—d	202—d	203—a	204—c
205—b	206—b	207—c	208—a	209—d	210—a	211—d	212—d	213—d	214—b	215—c	216—c
217—d	218—c	219—a	220—d	221—a	222—c	223—a	224—c	225—d	226—b	227—b	228—c
229—b	230—d	231—b	232—b	233—c	234—a	235—c	236—a	237—d	238—b	239—c	240—b
241—b	242—d	243—b	244—a	245—d	246—d	247—a	248—c	249—c	250—b	251—a	252—b
253—a	254—a	255—b	256—d	257—c	258—d	259—c	260—a	261—d	262—a	263—d	264—d
265—c	266—a	267—d	268—c								

EXPLANATION OF SELECTED QUESTIONS(*)

34. Maximum cellulose content is present in *Picea* (spruce) and hence it is the most important raw material in paper industry.
41. Largest ovule, largest egg and largest sperm in the plant kingdom are present in *Cycas*.
71. Nucellus is sporophytic tissue ($2n$) and endosperm in *Pinus* (gymnosperms) is haploid tissue (n). Thus the number of chromosomes is half of the nucellus, *i.e.*, 10.
105. Resin duct in *Pinus* is formed by splitting of cell walls, *i.e.*, schizogenous cavity.
128. Birbal Sahni discovered a fossil class pentoxylae of gymnosperms from Raj Mahal Hills in Bihar. He described a fossil gymnosperm *Williamsonia* from Raj Mahal Hills.
136. Root is sporophytic tissue ($2n$) whereas endosperm is gametophytic tissue (n).
148. The girdle traces or indirect traces enter the leaf after making a semicircle in *Cycas*.
152. As both diploid and haploid phases are equally represented in the life cycle of *Pinus*, hence life cycle pattern is haplodiplontic.
164. As fertilization in *Cycas* (gymnosperms) is by means of pollen tube, hence water is not necessary.
167. Presence of ciliated, motile sperms in *Cycas* indicates pteridophytic ancestry.
175. In *Pinus roxburghii*, trifoliar spur is present, hence outline of needle or leaf is triangular.
196. Bitegmic ovules in gymnosperms are found in *Gnetum* and *Ephedra* (order Gnetales).
200. Ephedrine alkaloid obtained from *Ephedra* is used in the treatment of cold, cough, etc.
214. *Sequoiodendron giganteum* (*Sequoia gigantea*) is having maximum age (*i.e.*, about 4000–5000 years), hence called 'father of forest'.
253. Wood of *Pinus* is compact and hard (pycnoxylic) and made up of only tracheids, *i.e.*, lacking vessels (homoxylous).
257. *Ginkgo* because of its primitive characters is called 'living fossil'.

TEST PAPER—UNIT-4

1. *Fritschiella tuberosa*, a terrestrial alga, was discovered by:
(a) Fritsch (b) Smith
(c) Iyenger (d) Desikachary

2. All isogamy, anisogamy and oogamy are found in which plant?
(a) *Ulothrix* (b) *Spirogyra*
(c) *Oscillatoria* (d) *Chlamydomonas*

3. Chromatophores are not found in:
(a) Rhodophyceae (b) Chlorophyceae
(c) Phaeophyceae (d) Bacillariophyceae

4. 'Red rust of tea' is caused by:
(a) *Puccinia* fungus (b) *Ustilago* fungus
(c) *Cephaleuros* alga (d) *Albugo* fungus

5. Nonmotile, thick-walled spores in algae are called:
(a) Zoospores (b) Aplanospores
(c) Hypnospores (d) Zygospores

6. 'Sewage oxidation ponds' have luxuriant growth of:
(a) Algae and bacteria (b) Algae and fungi
(c) Fungi and bacteria (d) Only algae

7. Which class of algae shows adaptability to extremes of environmental conditions?
(a) Chlorophyceae (b) Myxophyceae
(c) Rhodophyceae (d) Phaeophyceae

8. An alga with no flagellate phase is:
(a) *Ulothrix* (b) *Spirogyra*
(c) *Volvox* (d) *Chlamydomonas*

9. Red colour of Red Sea is due to:
(a) *Chlamydomonas nivalis*
(b) *Haematococcus*
(c) *Trichodesmium erythreum*
(d) Red algae

10. Spiral of chloroplast in *Spirogyra* is:
(a) Sinistral (b) Dextral
(c) Double helical (d) Circular

11. Algae are characterized by:
(a) Thalloid plant body (b) Aquatic habitat
(c) Unicelled sex organs (d) Pyrenoid

12. Each chloroplast in *Spirogyra* bears:
(a) Indefinite pyrenoids equidistant from each other
(b) Definite pyrenoids equidistant from each other
(c) Indefinite pyrenoids at unequal distances
(d) Only 10–20 pyrenoids

13. 'Germ theory of diseases' was given by:
(a) Ivanowski (b) Stanley
(c) Koch (d) Pasteur

14. The outer layer of cell wall of Gram +ve bacteria is of:
(a) Glycoproteins (b) Lipoproteins
(c) Teichoic acid (d) Muramic acid

15. Pasteurization of milk occurs at:
(a) 61.8°C for 20 minutes (b) 62.8°C for 30 minutes
(c) 68.2°C for 30 minutes (d) 62.8°C for 1 hr

16. Plague is a disease:
(a) Viral (b) Bacterial
(c) Mycoplasmal (d) None of these

17. Bacteriophage was discovered by:
(a) Stanley (b) T'wort
(c) Ivanowski (d) Mayer

18. Viroides have:
(a) Proteins only (b) DNA only
(c) RNA only (d) RNA and proteins

19. Bullet-shaped virus is:
(a) Rabies virus (b) Varicella
(c) Variola (d) Polio virus

20. The bacteria without cell walls are called:
(a) Bacterioids (b) L-form bacteria
(c) D-form bacteria (d) *Mycobacterium*

21. Lysogenic bacteria are having:
(a) Virulent phages (b) Prophages
(c) Both (a) and (b) (d) None of these

22. PPLO were first discovered by:
(a) Nocard and Raux (b) Pasteur
(c) Leeuwenhoek (d) None of these

23. Red pigment present in root nodules of legumes is:
(a) Phycoerythrin (b) Bacteriochlorophyll
(c) Leghaemoglobin (d) Bacterioviridin

24. 'Botulism' is caused by:
(a) Virus (b) *Staphylococcus* bacteria
(c) *Pseudomonas* bacteria (d) *Clostridium* bacteria

25. Who is known as father of Indian mycology?
(a) K.C. Mehta (b) Thind
(c) Iyenger (d) Butler

26. Fungi are like algae in that:
(a) These are non-vascular
(b) Unicellular and non-jacketed sex organs
(c) No embryo formation
(d) All of the above

27. 'Pin mould' is:
(a) Yeast (b) *Rhizopus*
(c) *Penicillium* (d) *Aspergillus*

28. 'Spontaneous creation theory' was put forward by:
(a) Ainsworth (b) Alexopaulous
(c) Needham (d) Butler

29. Which one of the following is a 'predacious fungus'?
(a) *Monoblepharis* (b) *Saprolegnia*
(c) *Arthrobotrys* (d) *Synchytrium*

30. Sexual reproduction by gametangial copulation occurs in:
(a) *Rhizopus* (b) Yeast
(c) Both (a) and (b) (d) None of these

31. 'Fairy rings' are found in:
(a) Rusts (b) Smuts
(c) Mushrooms (d) Yeast

32. 'Wonder drug' is obtained from:
(a) *Streptomyces venezualae*
(b) *Penicillium notatum*
(c) *Chlorella*
(d) *Claviceps*

33. A fungus used in prevention of cancer is:
(a) *Lycoperdon* (b) *Psaliotta*
(c) *Amanita* (d) *Clavatia*

34. 'Earth star' is:
(a) *Coprinus* (b) *Geaster*
(c) *Polyporus* (d) *Cyathus*

35. 'Invertase' enzyme is obtained from:
(a) *Aspergillus flavus*
(b) *Saccharomyces cerevisiae*
(c) *Penicillium camembertii*
(d) None of the above

36. Parasexuality in fungi was reported by:
(a) Butler (b) Mundkar
(c) Ainsworth (d) Pontecorvo

37. Species of *Rhizopus* are:
(a) Homothallic
(b) Heterothallic
(c) Mostly homothallic, rarely heterothallic
(d) Mostly heterothallic, rarely homothallic

38. Cyphallae in lichens are analogous to .... in higher plants:
(a) Palisade tissue (b) Mesophyll
(c) Stomata (d) Bundle sheath

39. Source of 'Litmus' is:
(a) *Lecanora* (b) *Cetraria*
(c) *Roccella* (d) *Parmelia*

40. Lichens are indicators of:
(a) Water pollution (b) SO_2 pollution
(c) Petroleum deposits (d) O_3 pollution

41. Which association is considered best in lichens?
(a) Consortium (b) Symbiosis
(c) Helotism (d) Proto-cooperation

42. An antibiotic of lichen origin is:
(a) Griseofulvin (b) Usnic acid
(c) LSD (Lysergic acid) (d) None of these

43. *Saccharomyces* grows best in:
(a) Salt water (b) Bread
(c) Sugary solution (d) Distilled water

44. Which is not present in cell wall of yeast?
(a) Lipid (b) Protein (c) Glucan (d) Cellulose

45. Mycelium is plant body of:
(a) Algae (b) Fungi
(c) Bryophyta (d) Pteridophyta

46. The ascus of yeast contains:
(a) 10 ascospores (b) 2 ascospores
(c) 4 or 8 ascospores (d) 1 ascospore

47. First vascular land plants are:
(a) Bryophytes (b) Pteridospermales
(c) Psilophytales (d) Psilotales

48. Pteridophytes differ from bryophytes in that:
(a) Former have multicellular and jacketed sex organs
(b) Seed development absent
(c) Antherozoides biflagellated
(d) Main plant body is sporophytic

49. 'Hay scented fern' is:
(a) *Dryopteris* (b) *Pteris*
(c) *Adiantum* (d) None of these

50. *Dryopteris* is:
(a) Homosporous
(b) Heterosporous
(c) Homosporous or heterosporous
(d) None of these

51. Fern prothallium is:
(a) Dioecious and protandrous
(b) Monoecious and protogynous
(c) Monoecious and protandrous
(d) None of the above

52. The term 'Stele' was first used by:
(a) Sachs (b) Douliot
(c) Van Tieghem (d) Van Tieghem and Douliot

53. 'Little club moss' is:
(a) *Lycopodium* (b) *Osmunda*
(c) *Selaginella* (d) *Isoetes*

54. Which is 'Resurrection plant'?
(a) *Marsillea* (b) *Salvinia*
(c) *Selaginella* (d) None of these

55. Trabeculated endodermis is the feature of:
(a) *Dryopteris* (b) *Selaginella*
(c) *Lycopodium* (d) None of these

56. Fern stele is:
(a) Dictyostele (b) Siphonostele
(c) Solenostele (d) Protostele

57. The venation of leaf in fern is:
(a) Parallel (b) Reticulate
(c) Dichotomous (d) Open furcate

58. Tallest pteridophyte is:
(a) *Woodsia* (b) *Cyathaea*
(c) *Drynaria* (d) *Anogramma*

59. Telome theory was put forward by:
(a) Bower (b) Zimmermann
(c) Van Tieghem (d) Campbell

60. The term 'Atracheata' is given to:
(a) Algae (b) Fungi
(c) Bryophyta (d) Pteridophyta

61. A protective covering 'Calyptra' in bryophytes is formed by:
(a) Wall of neck
(b) Wall of venter
(c) Stalk of archegonium
(d) Formed as a new structure

62. Sexual reproduction in bryophytes is:
(a) Isogamous (b) Anisogamous
(c) Oogamous (d) All of these

63. '*Liverworts of Western Himalayas*' was written by:
(a) P.N. Mehra (b) Ram Udar
(c) Mundkar (d) S.R. Kashyap

64. The bryophyte reported at maximum height (about 20,000 ft a.s.l.) is:
(a) *Buxbaumia* (b) *Dawsonia*
(c) *Aongstroemia* (d) *Fontinalis*

65. Most economically important bryophyte is:
(a) *Funaria* (b) *Sphagnum*
(c) *Riccia* (d) *Polytrichum*

66. 'Hornwort' is:
(a) *Riccia* (b) *Marchantia*
(c) *Anthoceros* (d) None of these

67. Alga-like, filamentous branched body produced by germination of spore in *Funaria* is called:
(a) Primary protonema (b) Secondary protonema
(c) Chloronema (d) Caulonelema

68. Rhizoids in *Funaria* are:
(a) Unicellular and smooth walled
(b) Unicellular and tuberculated
(c) Multicellular, branched with oblique septa
(d) Multicellular, branched with straight septa

69. Apophysis region of moss capsule is ...... in function:
(a) Assimilatory
(b) Conduction and mechanical
(c) Formation and dispersal of spores
(d) Retention of moisture

70. Spore of *Funaria* contains:
(a) Single chloroplast (b) 2 chloroplasts
(c) Many chloroplasts (d) No chloroplast

71. Which is the 'age of higher gymnosperms'?
(a) Mesozoic (b) Cenozoic
(c) Palaeozoic (d) Proterozoic

72. Ovule in gymnosperms is generally:
(a) Anatropous and bitegmic
(b) Orthotropous and bitegmic
(c) Orthotropous and unitegmic
(d) Anatropous and unitegmic

73. Wood of *Cycas* is:
(a) Porous (b) Pycnoxylic
(c) Manoxylic (d) None of these

74. 'Maiden Hair Tree' is:
(a) *Cycas* (b) *Ginkgo*
(c) *Pinus* (d) *Cedrus*

75. *Cycas* has:
(a) Largest egg (b) Largest ovule
(c) Largest spermatozoid (d) All of these

76. Maximum cellulose content occurs in:
(a) *Cycas* (b) *Pinus*
(c) *Picea* (d) *Cedrus*

77. 'Sago palm' is:
(a) *Cycas revoluta* (b) *C. circinalis*
(c) *C. rumphii* (d) *Pinus*

78. Circinate ptyxis is a feature of:
(a) *Cycas* (b) *Dryopteris*
(c) Both (a) and (b) (d) *Pinus*

79. Number of cotyledons in seed of *Cycas* is:
(a) 1 (b) 2
(c) Many (d) 4

80. For discovery of prions (slow viruses), Nobel Prize for 1997 had been given to:
(a) Prusiner (b) T'wort
(c) Stanley (d) Ivanowski

81. Which of the following statements is wrong?
(a) Naked seeds are seen in gymnosperms
(b) Endospores are produced by pteridophyta
(c) Basidiocarp is the fruiting body of fungus
(d) Capsule is the part of sporophyte of bryophyta

ANSWERS

1—c	2—d	3—b	4—c	5—c	6—a	7—b	8—b	9—c	10—a	11—d	12—a
13—d	14—c	15—b	16—b	17—b	18—c	19—a	20—b	21—b	22—b	23—c	24—d
25—d	26—d	27—b	28—c	29—c	30—c	31—c	32—b	33—d	34—b	35—b	36—d
37—d	38—c	39—c	40—b	41—c	42—b	43—c	44—d	45—b	46—c	47—c	48—d
49—a	50—a	51—c	52—d	53—c	54—c	55—b	56—a	57—d	58—b	59—b	60—c
61—b	62—c	63—d	64—c	65—b	66—c	67—a	68—c	69—a	70—c	71—a	72—c
73—c	74—b	75—d	76—c	77—a	78—c	79—b	80—a	81—b			

UNIT-4

ASSERTION AND REASON TYPE QUESTIONS

In the questions given below, two statements—an Assertion (A) and a Reason (R) are given. Give the appropriate response as:

(a) If both A and R are true and R is the correct explanation of A.
(b) If both A and R are true but R is not the correct explanation of A.
(c) If A is true but R is false.
(d) If both A and R are false.
(e) If A is false and R is true.

1. A: Definite chloroplasts are absent in photosynthetic bacteria but chromatophores are present.
R: Chlorophyll-a and chlorophyll-b are absent in bacteria.

2. A: In Gram +ve bacteria, stain does not come out when destaining is done with water and alcohol.
R: In cell wall of Gram +ve bacteria, both horizontal and vertical peptide linkages are present.

3. A: In bacteria, mitochondria are absent and mesosomes are respiratory structures.
R: Respiratory enzymes in bacteria are present on plasma membrane.

4. A: Bacteria are ubiquitous.
R: Bacteria occur in water, soil, air, animals, plants, snow and in hot water streams.

5. A: Cell membrane in bacteria is having typical tripartite structure.
R: Sterols are altogether absent in cell membrane of bacteria.

6. A: Typical 9 + 2 pattern of flagellum structure is absent in bacteria.
R: Flagellum of bacteria is chemically made of tubulin protein.

7. A: DNA in bacteria is double helical and circular.
R: G, C contents in bacterial DNA are lesser than A, T contents.

8. A: Ribosomes are evenly distributed in matrix in bacteria.
R: Endoplasmic reticulum is absent in prokaryotes.

9. A: Highly resistant single spore formed inside the bacterial cell is called endospore.
R: Ca ions, dipicolinic acid and peptidoglycans are present in concentric cortex layers of endospore.

10. A: Unboiled milk becomes sour earlier than boiled milk.
R: Lactic acid bacteria convert lactose of milk into lactic acid.

11. A: Botulism (a kind of food poisoning) is caused by *Xanthomonas* bacteria.
R: Neuromuscular junction is affected in botulism.

12. A: Archaebacteria can face extremes of conditions of temperature and pH.
R: Branched chain lipids are present in plasma membrane of archaebacteria.

13. A: Mycoplasma or PPLO have no definite shape, *i.e.*, pleomorphic and thus called 'jokers of microbiology'.
R: Smallest known prokaryotes without cell wall are mycoplasma.

14. A: Different plant and animal diseases are caused by mycoplasma.
R: Mycoplasmas are insensitive to penicillin.

15. A: Viruses are obligate parasites.
R: Both DNA and RNA are present in a virus.

16. A: Sub-viral infectious agents are called viroids.
R: Viroids cause persistent infections.

17. A: AIDS is called 'Death Warrant'.
R: AIDS virus has a liking for T-lymphocytes which produce antibodies.

18. A: Bacteria cannot survive in salted pickles.
R: In high salt concentration, bacteria get plasmolysed and killed.

19. A: 'Red snow' is caused by *Chlamydomonas nivalis* alga.
R: A red pigment haematochrome is present in the thick walls of hypnospores of *Chlamydomonas nivalis.*

20. A: *Cephaleuros* is an epizoic alga.
R: Red rust of tea is caused by *Cephaleuros*, a green alga.

21. A: Green algae are mostly marine.
R: Largest algae belong to class chlorophyceae of algae.

22. A: Cell wall of diatoms is silicified.
R: Unique type of spores called auxospores are characteristic of diatoms.

23. A: Blue-green algae show adaptability to extremes of environment.
R: Presence of gelatinous sheath and compactness of protein molecules in protoplasm are characteristic features of blue-green algae.

24. A: 'Palmella stage' is a characteristic feature of *Spirogyra.*
R: Palmella stage is a means of perennation.

25. A: *Ulothrix* filaments are felt as wet threads.
R: Outer layer of cell wall of *Ulothrix* is made of protopectin.

26. A: Sex organs in fungi are unicellular and non-jacketed.

R: There is no embryo formation in the life cycle of fungi.

27. A: There is a long, independent dikaryophase in ascomycetes class of fungi.

R: Clamp connections on dikaryotic hyphae are of universal occurrence in ascomycetes.

28. A: As deuteromycetes class of fungi lacks sexual stage, so it is called fungi imperfectii.

R: Perfect stage in fungus means sexual stage.

29. A: Most of the species of *Rhizopus* are heterothallic.

R: Zygospore formation occurs only between two oppositely strained hyphae in *Rhizopus*.

30. A: Fermentation property of yeast is the basis of baking as well as brewing industry.

R: C_2H_5OH formed in fermentation is the basis of baking industry whereas CO_2 is the basis of brewing industry.

31. A: Lichens do not grow in or near big cities.

R: Lichens are very sensitive to air pollution or specially SO_2 pollution.

32. A: Cyphellae in lichens are analogous to stomata of higher plants.

R: Cyphellae are loose areas in lower cortex of lichen thalli and these help in gaseous exchange.

33. A: Bryophytes are called amphibians of plant kingdom.

R: Bryophytes complete their vegetative phase on land but water is necessary for their reproductive phase.

34. A: The name 'Atracheata' has been given to bryophytes.

R: Bryophytes lack vascular tissue.

35. A: Members of class Hepaticopsida of bryophytes are commonly called 'Hornworts'.

R: These are called hornworts because of presence of horn-like gametophytes.

36. A: Sporophytes of bryophytes are always fully dependent upon gametophytes.

R: Chlorophyll and stomata are altogether absent in sporophytes of bryophytes.

37. A: *Sphagnum* is the most economically important bryophyte.

R: *Sphagnum* is used as packing material, in the preparation of moss sticks, as antiseptic absorbent bandages and also as a source of fuel.

38. A: Simplest sporophyte in bryophytes is of *Riccia*.

R: The sporophyte of *Riccia* is having only capsule; foot as well as seta are absent.

39. A: Spore on germination in *Funaria* gives rise to leafy gametophore.

R: Leaves of *Funaria* are having stomata and chlorophyll.

40. A: There are two rings or rows of peristomial teeth in *Funaria* capsule.

R: Inner ring of peristomial teeth is hygroscopic in nature.

41. A: Pteridophytes are called 'snakes of plant kingdom'.

R: Evolution of pteridophytes took place after bryophytes.

42. A: Rhizophores are characteristic of *Selaginella*.

R: In *Selaginella cuspidata*, rhizophores are absent.

43. A: An algal character is present in *Anthoceros* of bryophytes and *Selaginella* of pteridophytes.

R: Cells of thallus of *Anthoceros* and mesophyll cells of leaves of *Selaginella* contain chloroplasts with pyrenoids.

44. A: *Adiantum* is commonly called 'maiden hair fern'.

R: The petioles of *Adiantum* are long, shining, black hair-like structures as hair of women.

45. A: Coniferales is the highest order of gymnosperms.

R: Vessels are present in xylem of members of order Coniferales.

46. A: Pollens of *Cycas* are winged.

R: Exine of pollen of *Cycas* gives rise to wings.

47. A: Gymnosperms are naked seeded plants.

R: Ovary and hence fruit formation is absent in gymnosperms.

48. A: Water is not needed for fertilization in gymnosperms.

R: Fertilization is siphonogamous, *i.e.*, by means of pollen tube.

49. A: Fruticose are well branched leafy lichens.

R: These lichens are having upright and pendulous organizations attached to substratum of a discoid structure. (AIIMS 1995)

50. A: Symbiosis is also furnished by mycorrhiza.

R: In mycorrhiza, symbiosis is established between alga and fungus. (AIIMS 1996)

51. A: The viruses are not considered organisms.

R: Viruses are merely nucleoprotein particles and lack cytoplasm and metabolic machinery. (AIIMS 1998)

52. A: Eubacteria are found in three basic shapes: rod, round or spherical and spiral.

R: The *Cocci* and *Bacilli* may form clusters or chains of a length typical of a particular bacterium. (AIIMS 2000)

53. A: Red algae can survive in deep sea water.

R: These have phycocyanin and phycoerythrin which can easily trap the blue-green portion of light. (AIIMS 1999)

54. A: Some viruses have RNA but no DNA.

R: All viruses require a host cell to replicate. (AIIMS 1999)

55. A: Mosses are evolved from algae.

R: Protonema of mosses resembles certain green algae. (AIIMS 2001)

56. A: Viral diseases can be treated with antibiotics.

R: Viral genome is similar to host genome.

57. A: In bacteria, photosynthesis occurs by utilizing wavelengths longer than 700 nm.

R: Here the reaction centre is P-890.

58. A: Yeasts such as *Saccharomyces cerevisiae* are used in baking industry.

R: CO_2 produced during fermentation causes bread dough to rise by thermal expansion. (AIIMS 2003)

59. A: Many visitors to the hills suffer from skin and respiratory allergy problems.

R: Conifer trees produce a large quantity of wind-borne pollen grains. (AIIMS 2003)

ANSWERS

1. (a) 2. (a) 3. (a) 4. (a) 5. (b) 6. (c) 7. (b) 8. (a) 9. (a) 10. (a)
11. (c) 12. (a) 13. (a) 14. (b) 15. (c) 16. (b) 17. (a) 18. (a) 19. (a) 20. (c)
21. (d) 22. (b) 23. (a) 24. (c) 25. (a) 26. (b) 27. (d) 28. (a) 29. (a) 30. (c)
31. (a) 32. (a) 33. (a) 34. (a) 35. (d) 36. (d) 37. (a) 38. (a) 39. (d) 40. (c)
41. (a) 42. (b) 43. (a) 44. (a) 45. (d) 46. (d) 47. (a) 48. (a) 49. (c) 50. (c)
51. (a) 52. (b) 53. (a) 54. (b) 55. (a) 56. (d) 57. (b) 58. (a) 59. (b)

UNIT-5

- Morphology of Angiosperms
- Fruits and Dispersal of Seeds and Fruits
- Embryology of Angiosperms
- Plant Anatomy
- Test Paper—Unit–5
- Assertion—Reason Type Questions (Unit–5)

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Morphology of Angiosperms

- ☐ Angiospermic plant and forms of angiosperms
- ☐ The Root: Characters of root, zones or parts of a root, types of roots, modifications of roots, functions of roots
- ☐ The Stem: Characters of stem, buds, modification of buds, types or forms of stems, modifications of stem, functions of stem
- ☐ The Leaf: Types of leaves, parts of a foliage leaf (leaf base, petiole, lamina), venation, vernation and ptyxis, simple and compound leaves, phyllotaxy, modifications of leaves, functions of leaf
- ☐ Inflorescence
- ☐ Flower
- ☐ Fruit
- ☐ Seed: Parts of seed, seed germination, seed dormancy

ANGIOSPERMIC PLANT AND FORMS OF ANGIOSPERMS

Angiosperms constitute dominant flora of nowadays, as out of total 3,45,000 species of plant known today, they are about 2,00,000 in number.

A typical angiospermic plant is **sporophytic** ($2n$) and is having **vegetative parts and reproductive parts. Vegetative parts** or organs of an angiospermic plant are **root, stem** and **leaves.** Roots collectively constitute **root system,** which generally constitute the **below ground** portion of the plant body. This root system is responsible for fixing the plant in the soil and is also responsible for water and mineral salts absorption.

The stem with its branches and leaves constitute **shoot system,** which is generally **above ground** or aerial part of the plant. Support and conduction functions are assigned to stem and its branches whereas assimilation or photosynthetic or food making function is assigned to leaves. Flower formation is the **transitional phase** in the life cycle of an angiospermic plant (change from vegetative phase to reproductive phase). Flower is the most important part of the plant and is concerned with reproduction (hence forms **reproductive part**). Flower is considered to be **modified shoot,** with its leaves modified variously to perform different functions (*e.g.*, sepals, petals, stamens, carpels). Calyx and corolla are the accessory whorls of a typical flower whereas androecium and gynaecium constitute the **necessary whorls** as these are male and female reproductive organs respectively. Androecium is having **stamens** as its units whereas **carpels** are the units of gynaecium. A typical stamen is having **filament, connective** and **anther** as its parts. Anther is the fertile part in which pollens or pollen grains are produced, which in turn give rise to **male gametes** in further development. A typical carpel is having **stigma, style** and **ovary** as its 3 parts. Ovary is the fertile portion in which ovules are present. Ovule is having **embryo sac,** in which egg cell or female gamete is present.

After pollination and fertilization, zygote and hence embyro develops inside ovule. The **ripened ovule** with embryo is called **seed.** The **ripened ovary** with ovules constitute **fruit and thus seeds are present inside fruit,** hence called Angiosperms, *i.e.*, plants with encased or covered seeds or **covered seeded plants.**

Seed is having **embryo,** which is miny or tiny future plant. The seed on germination gives rise to **new plant or seedling** (from embryo).

Forms of angiosperms

A vast variety of angiospermic plants is present. These are classified into different types on different bases. The main classification of angiosperms are:

(A) Types of angiosperms on the basis of form

On the basis of form, angiosperms are of following types:

1. **Herbs:** These are plants which are non-woody and aerial parts are not persistent. Further their stem is short,

delicate and green (herbacious), *e.g.*, gram, wheat, spinach, mustard, radish, etc.

- o Banana (*Musa*) is one of the largest perennial herbs.

2. Shrubs : These are woody plants and are branched near the ground, stem is not much developed into clear trunk, *e.g.*, rose, China-rose, croton, duranta, etc.

3. Trees : These are woody plants, which are branched at some height and thus have much developed trunk. Trees are further of different types as :

(a) Excurrent or Conical : These are conical in shape, *i.e.*, having basal thicker portion and gradually thinner or tapering portion above. Further branches are arranged in acropetal succession, *e.g.*, *Pinus, Araucaria, Eucalyptus, Casuarina*, etc.

(b) Caudex or Palm like or Columnar : These have unbranched stem, having a crown of leaves at apex, *e.g.*, *Phoenix, Cycas, Areca* (supari), *Borassus*, etc.

(c) Deliquescent or Decurrent : In these, due to death of apical bud of stem after some time, branches and sub-branches grow vigorously and spread in different directions, *e.g.*, Ficus (banyan), *Tamarindus, Mangifera* (mango), *Dalbergia* (shisham), etc.

4. Culms : In these plants, stem is having very clear nodes and internodes (jointed stem). Here nodes are solid and internodes are generally hollow, *e.g.*, Grasses (members of Gramineae) and Sedges (members of Cypraceae).

(B) Types of angiosperms on the basis of life span

On the basis of life span, plants are of following types:

1. Annuals : Such plants which complete their life cycle within one season, are called annuals, *e.g.*, mustard, rice, wheat, groundnut, gram, etc.

- o Such annuals which complete their life within a brief or short (generally 4-6 weeks) period of time, are called **ephemeral annuals or ephemerals**, *e.g.*, *Argemone* (pili katili), *Artemisia, Astragalus*, etc.

2. Biennials : Such plants which complete their life cycle in two growing seasons (*i.e.*, complete their vegetative phase in first season and reproductive phase in second season), are called **biennials**, *e.g.*, carrot, radish, turnip, cabbage, etc.

3. Perennials : Such plants which grow for a number of seasons or for many years, are called **perennials**. They may produce flowers and fruits every year (*i.e.*, **polycarpic**), *e.g.*, apple, mango, lemon, neem, etc., or may produce flowers and fruits once in life (*i.e.*, **monocarpic**), *e.g.*, *Agave americana* (century plant) and *Bambusa bamboos* (bamboo).

- o The **century plant** flowers after about 100 years and after flowering dies.

(C) Types of angiosperms on the basis of mode of nutrition

1. Autotrophic plants : The plants which can manufacture their own organic food from inorganic substances, are called autotrophic or autophytes. These are of two types:

(a) Photoautotrophs or Photoautotrophic plants : These manufacture their food in presence of chlorophyll and light from CO_2 and $H_2O$by the process of photosynthesis, *e.g.*, most of the green plants.

(b) Chemoautotrophs or Chemosynthetic plants : These manufacture their food using chemical energy (not light energy) without presence of chlorophyll, *e.g.*, chemosynthetic bacteria.

2. Heterotrophic plants : The plants which are unable to manufacture their own food are called heterotrophic or heterotrophs. These are of following types:

(a) Saprophytes or Saprophytic plants
(b) Parasites or Parasitic plants
(c) Symbionts or Symbiotic plants
(d) Insectivorous or Carnivorous plants

- (for these heterotrophs, see 'Special modes of nutrition' in plant physiology).

THE ROOT

Root is an important vegetative part of the plant mainly responsible for nutrition and support. The main root, primary root or tap root is formed from the radicle. The lateral branches of main root are called secondary roots which are further branched to form tertiary roots. At the apex of root, root cap is present. The lateral or side branches arise from pericycle, *i.e.*, endogenous.

The main root or tap root along with its branches comprise root system. It is the descending, non-green underground part, lacking nodes, internodes, buds and leaves. It is positively geotropic and negatively phototropic.

- o In a hydrophyte *Podostemon*, root performs the function of assimilation and reproduction. **It is a plant that is all root.**
- o Roots are absent in some angiosperms, *e.g.*, *Utricularia, Ceratophyllum, Wolffia, Balanophora, Cuscuta, Myriophyllum*, etc.

Zones or Parts of a root

A root consists of four zones or regions from the lower most part to the upper most part. These are:

(i) Root cap
(ii) Meristamatic region or main growing region
(iii) Zone of elongation
(iv) Maturation zone

(i) Root cap : Root cap is present at the apex of root. It is made up of thin-walled cells. The main function of root cap

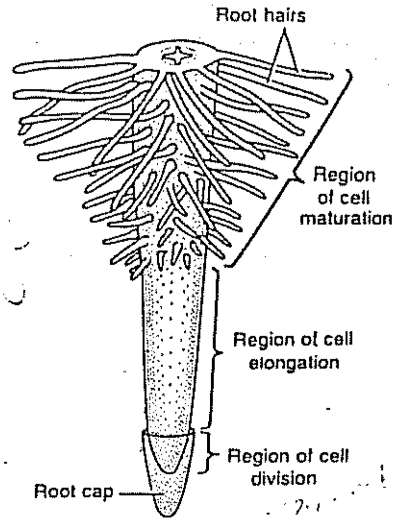

Fig. 15.1. Regions or zones of root

is to protect the young growing cells of apical region. Generally a simple root cap is present besides some exceptions, *e.g.*, in *Pandanus* (screw pine) multiple root cap is present while in aquatic plants, *i.e.*, hydrophytes, the apical portion is protected by root pocket in place of root cap, *e.g.*, *Eichhornia, Pistia, Lemna*, etc.

(ii) Meristematic zone : This zone is present just above the root cap. In this region cells divide actively hence it is the main growing region of the root. The cells are thin-walled lacking intercellular spaces.

(iii) Zone of elongation : This zone consists of elongated cells. It increases the length of the root. In later stages, a large central vacuole filled with cell sap is present in each cell. Zone of elongation is few millimetres in length.

(iv) Maturation zone : This zone is characterized by the presence of unicellular root hairs formed by the epidermal cells. The cells of this region become rigid. This region is few centimetres long.

Types of roots

Roots are divided into two types:

(i) Tap roots

(ii) Adventitious roots

(i) Tap root : Tap root or primary root develops from the radicle. It forms lateral branches or secondary roots which are further branched to form tertiary roots. Thus tap root along with its branches, *i.e.*, secondary and tertiary roots form tap root system. It is generally found in dicotyledons.

(ii) Adventitious roots: These roots develop from any part of the plant instead of radicle. Adventitious roots can be grouped into three types on the basis of their appearance:

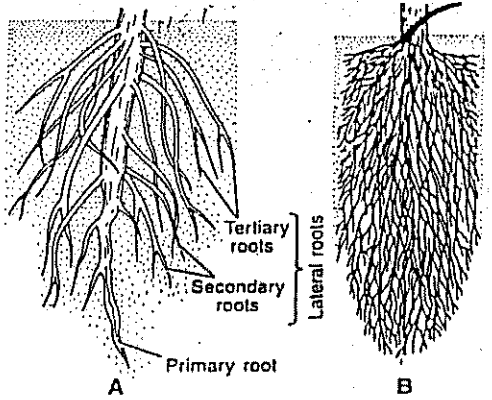

Fig. 15.2. Root types A. Tap root B. Fibrous or adventitious root

(a) Roots arising from the base of the stem, *e.g.*, maize, wheat, rice, onion, etc.

(b) Roots arising from the leaf, *e.g.*, *Bryophyllum, Pogostemon*, etc.

(c) Roots developing from the nodes and internodes of the stem, *e.g.*, *Ficus* (banyan), *Pothos* (money plant), etc.

Modifications of roots

In order to carry-out some special functions, *i.e.*, assimilation, storage, etc., the roots are modified into different forms. This modification takes place both in tap roots as well as in adventitious roots.

(I) Modification of tap root

(i) Conical : These roots have broad base tapering towards the apex, *e.g.*, *Daucas carota* (carrot). Conical roots perform the function of storage.

(ii) Fusiform : In these roots the middle portion becomes thicker and tapers on both the ends, *e.g.*, *Raphanus sativus* (radish).

(iii) Tuberous : Because of the irregular shape of the root, the food is stored in any portion, *e.g.*, *Mirabilis jalapa* (4 O' clock plant).

(iv) Napiform : The upper portion of these fleshy roots is inflated or swollen which tapers towards the lower end, *e.g.*, *Brassica rapa* (turnip), *Chenopodium album*.

(v) Nodulated : The plants of the Leguminosae family are characterised by the presence of nodules on branches of roots in which nitrogen fixing bacteria are present, *e.g.*, *Cicer arietinum* (gram), *Arachis hypogea* (peanut), etc.

(vi) Pneumatophores or Respiratory roots : In mangrove plants, *i.e.*, plants growing in saline marshes, the branches of tap root grow vertically upwards showing negative geotropism. These roots are called pneumatophores, which have minute pores on their exposed portion called pneumathodes to take O_2, *e.g., Rhizophora, Avicenia, Heritiera,* etc., Mangrove plants are found in the sunderbans of West Bengal.

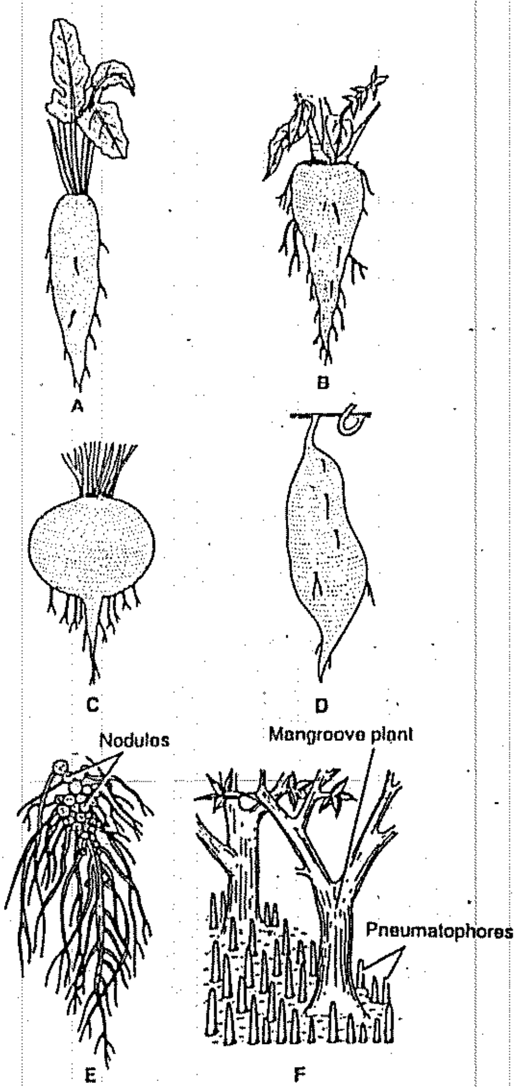

Fig. 15.3. Tap root modifications A. Fusiform B. Napiform C. Conical D. Tuberous E. Nodulated F. Pneumatophores

(II) Modification of adventitious roots

(i) Fasciculated roots : From the base or lower nodes of stem these tuberous roots arise in groups, *e.g., Dahlia, Asparagus, Ruellia,* etc.

(ii) Tuberous roots : These roots become fleshy because of storing food and have no definite shape, *e.g., Ipomoea batatus* (sweet potato).

(iii) Nodulose roots : The apex of these roots become swollen because of the accumulation of food, *e.g., Maranta, Curcuma amanda,* etc.

(iv) Moniliform roots : These are also called beaded roots because of their bead like appearance. Such roots are swollen at various places, *e.g., Momordica* (bitter gourd), *Portulaca* (rose moss) *Cyperus, Vitis,* etc.

(v) Annulated roots : In these roots swelling occurs at various places because of which the shape of roots look like the closely placed rings, kept one above the other, *e.g., Psychortia, Cephaelis,* etc.

(vi) Stilt roots : In some plants roots are formed from the nodes of lowermost portion of the stem and provide mechanical support to the plant by fixing it in soil firmly, *e.g., Pandanus tinctorius* (screw pine), *Zea mays* (maize), *Saccharum officinarum* (sugar cane), etc.

(vii) Prop roots : In some plants roots arise from branches and enter the soil. Thus they provide mechanical support to densely branched, huge trees, *e.g., Ficus benghalensis* (banyan), *Ficus elastica* (Indian rubber), etc.

(viii) Climbing roots : In some climbers roots are formed from the nodes of stem which help the plant to climb, *e.g., Pothos* (money plant), *Piper betle* (pan), etc.

(ix) Epiphytic roots : Some epiphytes, *e.g.,* (orchids) have aerial roots. In these roots the outer covering is made up of spongy tissue, the velamen which absorbs moisture from air.

(x) Floating roots : In some aquatic plants, *e.g., Jussiaea,* two types of roots are formed from the nodes of the stem. One remains inside the water while other remain in air helping the plants in floating.

(xi) Parasitic roots : Some parasitic plants develop sucking roots or haustoria which enter the host plant fulfilling the purpose of nutrition, *e.g., Cuscuta* (Dodder), etc.

(xii) Assimilatory roots : In some plants the roots start manufacturing food after developing chlorophyll, *e.g., Tinospora, Trapa,* etc.

(xiii) Mycorrhizal roots : In some plants the roots bear fungal hyphae which function as root hair, *e.g., Pinus.*

(xiv) Clinging roots : These roots arise from the nodes of stem and penetrate the stem of host plant, *e.g.,* Orchids, etc.

(xv) Reproductive roots : In some plants, *e.g. Trichosanthes dioica* (parwal), vegetative buds are formed by roots which form new plants.

(xvi) Root thorns : Roots of some plants arise from the stem and change into thorns, thus performing the protective function, *e.g., Pothos* (money plant).

(xvii) Contractile roots : In some plants the apical portion of some thick roots of the underground stem contract and help the plant fixing in soil, *e.g., Crocus, Allium cepa* (onion).

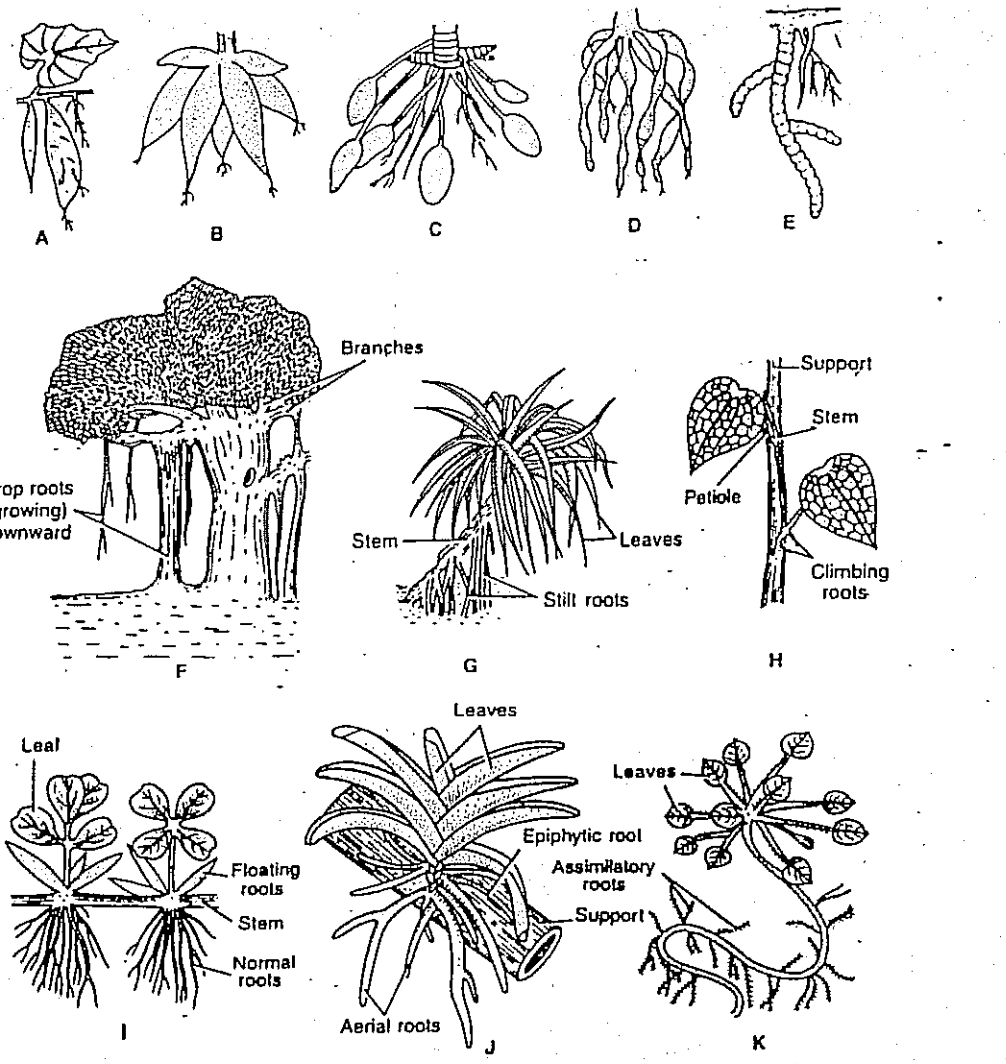
A
B
C
D
E
Branches
Prop roots (growing) downward
F
Stem
Leaves
Stilt roots
G
Support
Stem
Petiole
Climbing roots
H
Leaf
Floating roots
Stem
Normal roots
I
Leaves
Epiphytic root
Support
Aerial roots
J
Leaves
Assimilatory roots
K

Fig. 15.4. Adventitious roots modifications A. Tuberous root B. Fasciculated root C. Moniliform root D. Nodulose root E. Annulated root F. Prop roots G. Stilt roots H. Climbing roots I. Floating roots J. Epiphytic roots K. Assimilatory roots

Functions of roots

(i) Roots support the plant by keeping it fixed firmly in the soil.

(ii) Root absorbs water and minerals.

(iii) Store food inside them.

(iv) Roots hold the soil particles together.

THE STEM

Stem is the aerial part of the plant which develops from plumule. It is positively phototropic and negatively geotropic. Stem along with its leaves and branches forms the shoot system. Stem is the ascending portion of the plant having nodes and internodes. Leaves and branches are formed on the nodes of the stem. In stem, branches are exogenous in origin. The hairs or trichomes found on the stem may be unicellular or multicellular.

Buds

A bud is a condensed, immature, young shoot having undeveloped internodes because of which the leaves become overlapped and the bud acquires a compact structure.

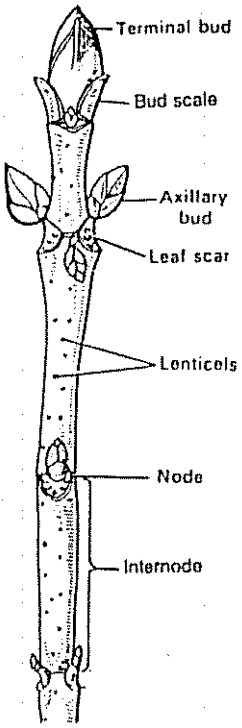

Fig. 15.5. Position of buds

- Cabbage (*Brassica oleracea* var. *capitata*) is the largest bud.

(I) Apical buds

These buds are present at the terminal or apical end and are meant for increasing the plant height.

(II) Lateral buds

These buds develop on stem or on branches at any side. Depending upon their place of occurrence, lateral buds may be:

(i) **Axillary,** *i.e.*, formed in the axil of leaf or

(ii) **Accessory,** *i.e.*, occurring on the lateral sides of axillary buds.

(III) Adventitious buds

These buds occur at different places other than apical or lateral position. Adventitious buds may be:

(i) **Foliar buds,** appearing on leaves, *e.g.*, in *Bryophyllum Begonia, Kalanchoe.*

(ii) **Radical buds,** developing on roots, *e.g.*, *Ipomea batatus* (sweet potato), *Dalbergia.*

(iii) **Cauline buds,** developing on stem, *e.g.*, rose.

Modification of buds

Sometimes the buds are modified into different structures performing different functions. Buds may be modified into:

(i) **Thorns,** *e.g.*, *Citrus* (lemon), *Carissa* (karonda), *Duranta*, etc.

(ii) **Bulbils :** These are fleshy buds meant for vegetative reproduction, *e.g.*, *Chlorophytum, Allium cepa* (garlic), *Allium sativum* (onion), etc.

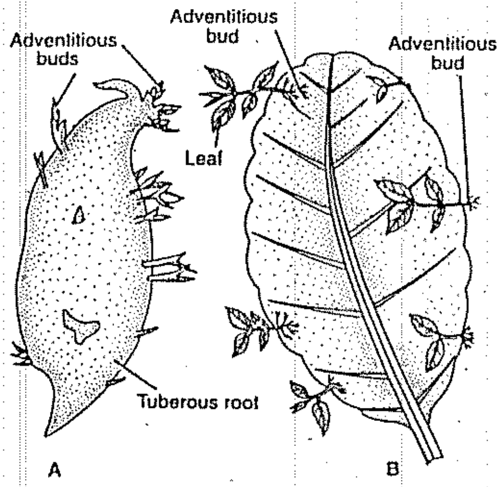

Fig. 15.6. Types of adventitious buds A. Radical buds of sweet potato B. Foliar buds of *Bryophyllum*

(iii) **Tendrils :** Sometimes both **floral buds** (bud developing into flowers), *e.g.*, *Cardiospermum* and **vegetative** buds, *e.g.*, *Passiflora* (passion flower) are modified into tendrils.

Types or Forms of stems

Mainly the stem is the aerial part of the plant but sometimes it becomes underground to perform some special function.

The aerial stems may have upright, stout and strong stem or may have feeble or weak stem.

I. Upright stout stem

The aerial stem having erect and strong stem. These may be:

(i) **Excurrent stems :** In these stems both main axis as well as lateral branches grow continuously. Thus the tree acquires cone like shape, *e.g.*, *Pinus, Casuarina.*

(ii) **Deliquescent stems :** When the lateral branches grow more rapidly than the main axis, the tree acquires a rounded shape, *e.g.*, *Mangifera indica* (mango), *Delonix regia*, etc.

(iii) **Caudex :** When the stem remains unbranched, strong and cylindrical, *e.g.*, *Cocos nucifera* (coconut) and some palms.

(iv) Culm : The plants having stem which has solid nodes and hollow internodes, *e.g.*, *Triticum vulgare* (wheat), *Bambusa arundinacea* (bamboo).

II. Feeble or Weak stems

The plants which cannot remain straight because of their weak stems. These may be:

(i) Creepers : These plants creep on the ground having roots at the nodes, *e.g.*, grasses.

(ii) Trailers : These plants grow prostrately and spread over the field. Roots are not formed at nodes, *e.g.*, *Portulaca*, *Tridex*, *Boerhaavia*, etc.

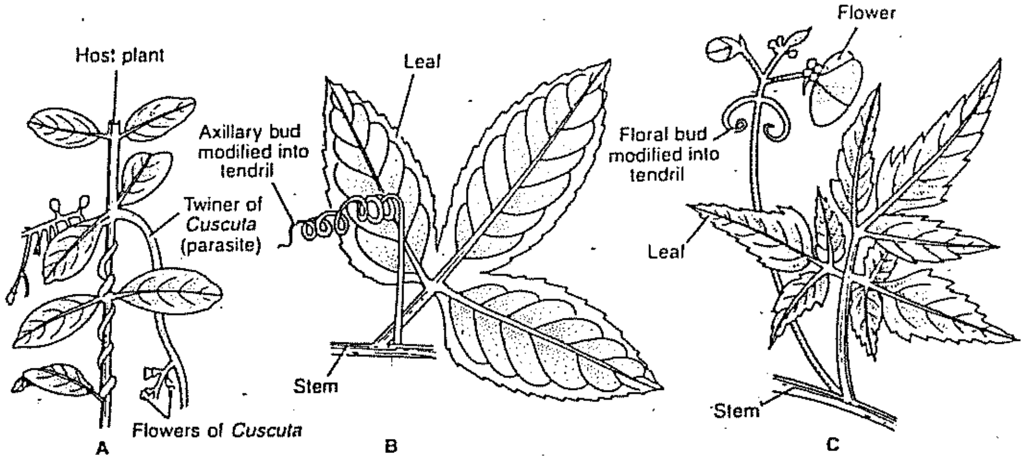
Host plant
Leaf
Axillary bud modified into tendril
Twiner of *Cuscuta* (parasite)
Flowers of *Cuscuta*
Stem
A
B
Flower
Floral bud modified into tendril
Leaf
Stem
C

Fig. 15.7. Stem Climbers A. Twiner of *Cuscuta* B. Tendrils of *Passiflora* C. *Cardiospermum* tendrils

(iii) Climbers : In these plants special structures are formed with the help of which the stem climbs up. These may be:

(a) Twiners or Stem climbers : The plant makes spiral coiling around any support, *e.g.*, *Cuscuta*, *Clitoria*, *Tinospora*, etc.

(b) Root climbers : The roots formed at the nodes of stem attach with the support, *e.g.*, *Pothos* (money plant), *Piper betle* (pan), etc.

(c) Tendrils : These are coiled structures which may be the modification of a leaf, *e.g.*, *Lathyrus* (sweet pea), a leaflet, *e.g.*, *Pisum sativum* (pea), a branch, *e.g.*, *Passiflora*, a branch tip, *e.g.*, *Vitis vinifera* (grape), a floral bud, *e.g.*, *Cardiospermum*, *Antigonon* or stipules, *e.g.*, *Smilax*.

(d) Lianas is a long, woody climber, *e.g.*, *Bauhinia*, *Gnetum*, *Hiptage*, etc.

Modifications of stem

Sometimes the stem is modified into various forms to perform different functions of storage, synthesis, vegetative propagation, perrenation, etc. Different modifications of stem are:

(A) Underground modifications
(B) Sub-aerial modifications
(C) Aerial modifications

(A) Underground modifications of stem

(a) Tuber : It is the branch of main stem which accumulates or stores food in it and swells up. On the surface of tuber many axillary buds or eyes are formed which are capable of growing into new plant under favourable conditions, *e.g.*, *Solanum tuberosum* (potato). (Fig. 15.8)

(b) Rhizome : It is a branched, prostrate horizontally growing stem having nodes and internodes. On the nodes sessile scale leaves are formed which bear buds in their axil. The lower portion of nodes gives rise to adventitious roots. These buds remain dormant but on approach of favourable condition give rise to aerial shoots, *e.g.*, *Canna*, *Zingiber officinale* (ginger), *Curcuma domestica* (turmeric), *Elattaria*, *Amomum*, etc.

- o Usually the rhizomes are horizontal but sometimes they grow vertically, *e.g.*, *Alocasia*, canna and sugar cane. Vertical rhizome is also called **root-stock.**

(c) Corm : This is a spherical, branched, vertically growing thick underground stem with **more diameter than length.** Corm usually bears reduced internodes having few axillary buds in the axil of scale leaves which grow into new corms. Adventitious roots are formed from the base of nodes. On approach of favourable conditions the terminal bud forms the aerial branch which later on dries up, *e.g.*, *Crocus sativus* (saffron), *Gladiolus*, *Colocasia esculenta* (arvi), *Amorphophallus*, etc.

(d) Bulb : In bulb the stem is **highly reduced** and can be seen only as a disc-like structure. On this disc are present

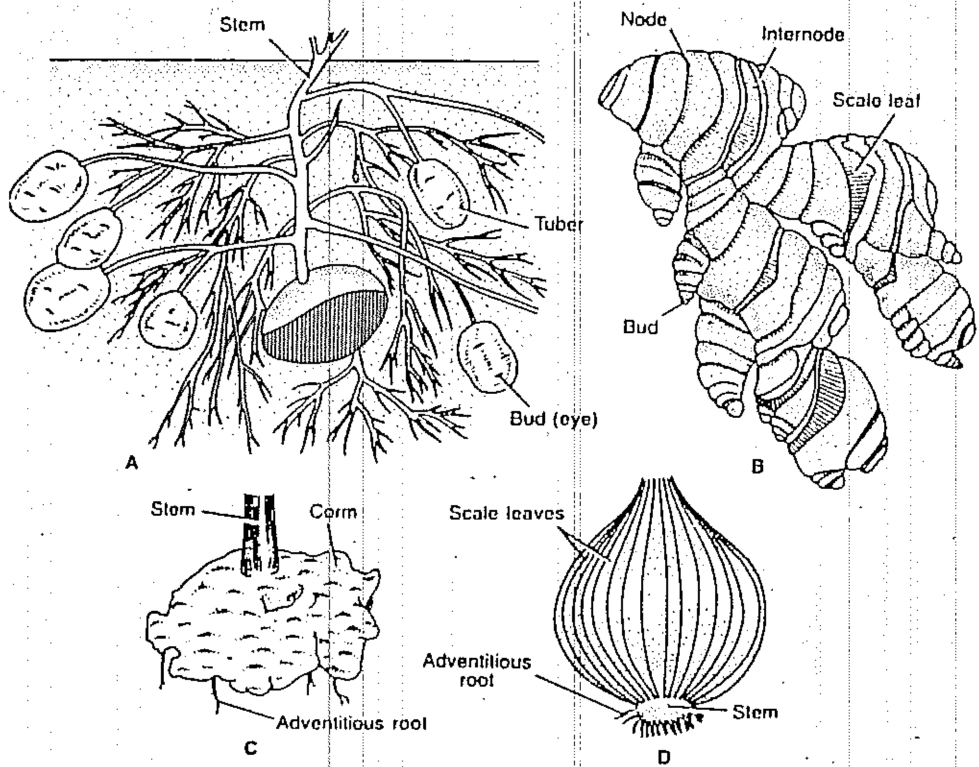
Stem
Tuber
Bud (eye)
A
Node
Internode
Scale leaf
Bud
B
Stem
Corm
Adventitious root
C
Scale leaves
Adventitious root
Stem
D

Fig. 15.8. Underground modifications of stem A. Tubers of potato B. Rhizome of ginger C. Corm of *Amorphophallus* D. Bulb of onion

numerous fleshy scaly leaves covering a central terminal bud. Both the disc and scaly leaves collectively are called bulb.

In some plants the inner scaly leaves are arranged in a concentric manner while the outer leaves becomes dry and form a **tunic** or covering, *e.g., Allium cepa* (onion). These bulbs are called tunicated bulbs. But in some bulbs the fleshy scale leaves are distinct and are called cloves. The group of cloves is covered by a thin tunic, *e.g., Allium sativum* (garlic).

- Characteristic smell of onion is due to **Sulphur-allyl sulphide** present in fleshy leaves.

(B) Subaerial modifications

In some plants the stem is feeble or weak and aerial part of it grows horizontally on the ground while some part remains underground. Lateral branches and adventitious roots are formed at the stem. Vegetative propagation takes place by means of these lateral branches. Subaerial modification may be of different kinds:

(a) **Runner :** It grows prostrately on the surface of soil. Stem consists of long internodes. Aerial branches are formed from the axil of scaly leaves which are present on the nodes while the roots arise from the lower side, *e.g., Cynodon* (doob grass), *Hydrocotyle, Oxalis* (wood sorrel), etc.

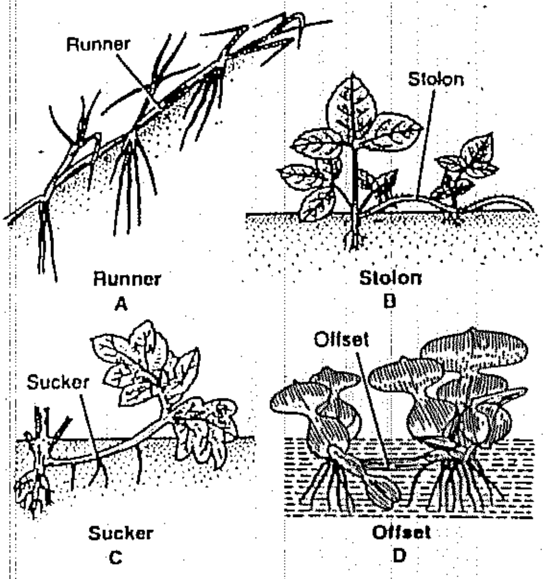
Runner
Runner
A
Stolon
Stolon
B
Sucker
Sucker
C
Offset
Offset
D

Fig. 15.9. Subaerial stem modifications A. Runner B. Stolon C. Sucker D. Offset

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